# POWER

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## What Does a Pound of Babbitt Cost?

TO ASK what is the most expensive part of a machine would seem strange perhaps, but a very definite answer to such question can often be given. The part that wears out, breaks or gets out of adjustment most often is unquestionably the most expensive part.

Babbitt metal is quoted variously according to grade and local market. But whether it be fifteen cents or fifty cents a pound makes relatively little difference in the last analysis, for the cost of the metal itself is but a small part of the cost of a bearing for which it may be used. When one adds together metal cost, labor of casting and the cost due to loss of service from the equipment or machine while undergoing repairs, it is evident that the babbitt once in place may literally be "almost worth its weight in gold."

A BREAKDOWN once in a while is to be expected. A repetition of such a break from the same cause requires careful investigation. A third break or frequent repetitions of interruption from a single cause represent something worse than a bad habit. The part, the machine or the man that is to blame has to change or be eliminated. Permanently, such part or man is too expensive at any price.

When figuring costs of maintenance or repair, all these factors must be taken into account. As in public utility service, so also in individual power plants, continuity of service is, next to safety, a prime requisite. Anything that prevents regular service creates expense—not only the direct cost for a new part, but also the cost of its installation and the still greater element of expense, the loss of production during interference with service.

# Quincy Hoist—Largest in World

By THOMAS WILSON

*Compound condensing hoist with two high-pressure and two low-pressure cylinders, 32 and 60 x 66 in., has an ultimate winding capacity of 13,300 ft. of 1⅝-in. rope in single layer, the greatest on record. The engine with condensing equipment weighs 1,765,000 lb. and the enormous cylindro-conical drum, 30 ft. long and 30 ft. in diameter at the middle section, 516,000 lb. The hoist operates in balance, raising 20,000 lb. of rock per trip at a rope speed of 3,200 ft. per minute.*

ON NOV. 9, 1920, the largest hoisting engine in the world was put into commission at the No. 2 shaft of the Quincy Mining Co., of Hancock, Mich. In size of cylinders and rope-winding capacity it surpasses the famous Tamarack hoist, which in general type it closely resembles except that it is cross-compound condensing rather than employing four simple cylinders. It has the same V-type frame arrangement, the two high-pressure cylinders being inclined to the horizontal at an angle of 45 deg. and connected to a common crankpin turning the drum shaft above at the apex of the triangle. The two low-pressure cylinders are similarly placed at the opposite end of the drum, the latter being the largest of its kind ever built.

The low-pressure pistons are each supported by a crosshead and tail guide. All four cylinders have separate throttle valves, a disc-type valve being employed for the high-pressure cylinders and a valve of the rocking type for the low-pressure cylinders. Between each pair of high- and low-pressure cylinders is a reheating

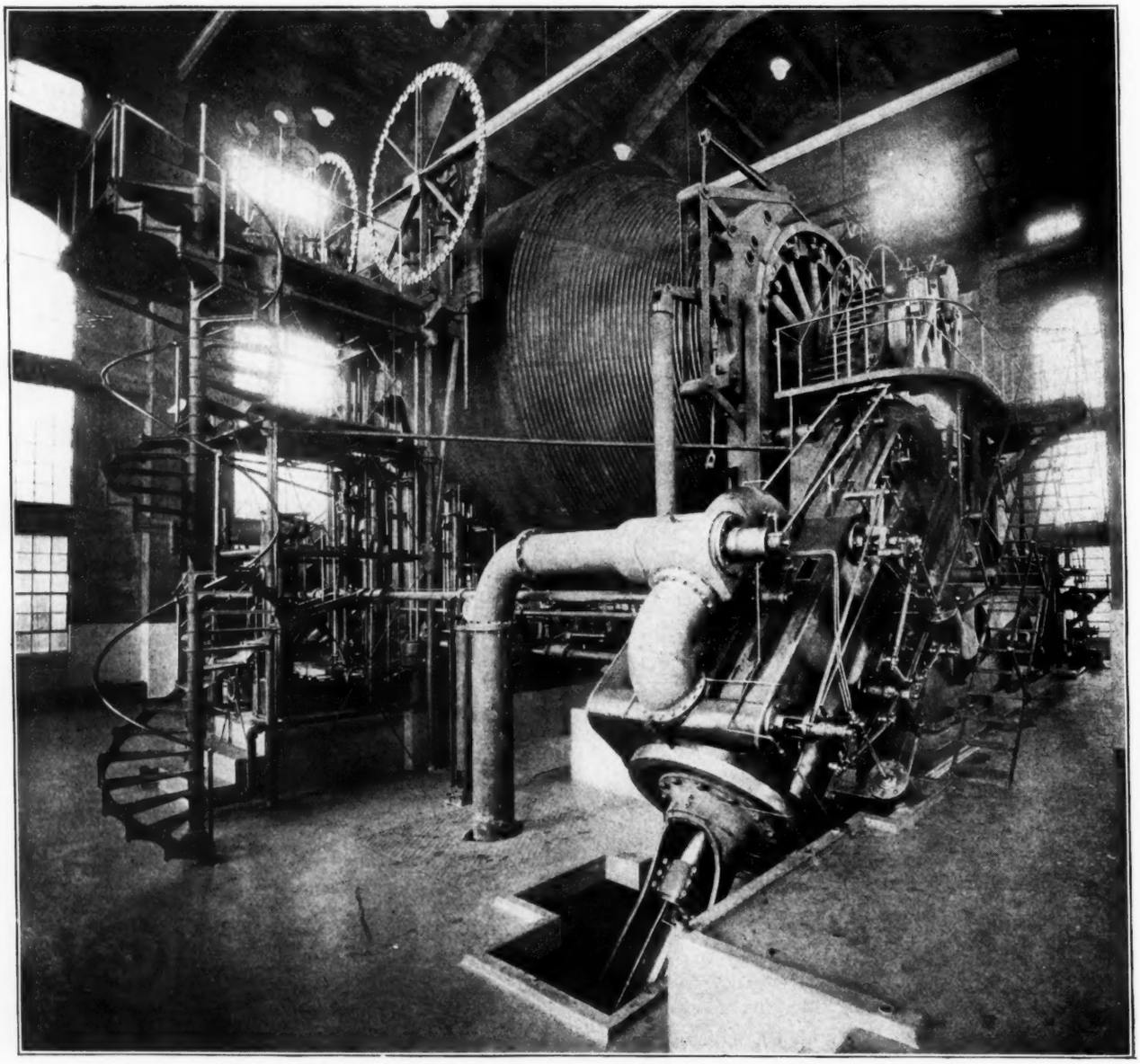

FIG. 1. THE BIG CROSS-COMPOUND CONDENSING HOIST AT THE QUINCY MINING COMPANY

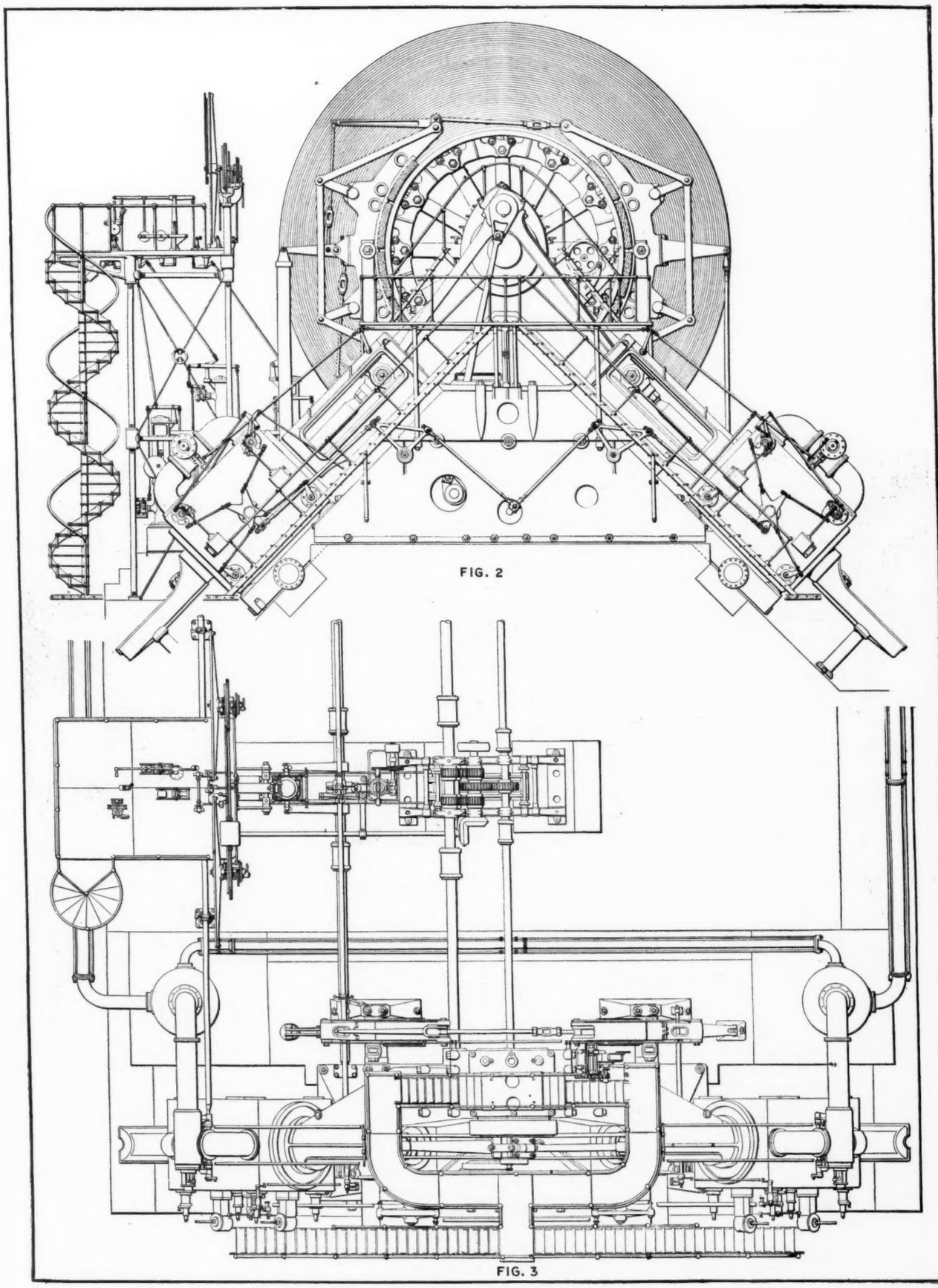

FIG. 2

FIG. 3

FIG. 2. END VIEW OF HOIST, SHOWING VALVE GEAR, BRAKE AND GOVERNING MECHANISM. FIG. 3. PLAN OF ONE-HALF THE HOIST, SHOWING FOUR-GEAR REVERSING MECHANISM ON THE CENTER

receiver in which the pressure, depending on the operation, approximates 35 lb. These receivers, as well as all four cylinders, are steam-jacketed with high-pressure steam drawn from the boilers through a reducing valve.

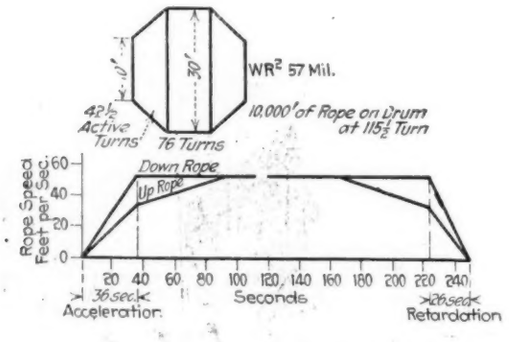
WR² 57 Mil.
10,000' of Rope on Drum at 115½ Turn
42½ Active Turns
76 Turns
Down Rope
Up Rope
Rope Speed Feet per Sec.
0 20 40 60
20 40 60 80 100 120 140 160 180 200 220 240
Seconds
36 sec. Acceleration
26 sec. Retardation

FIG. 4. ROPE SPEED DIAGRAM

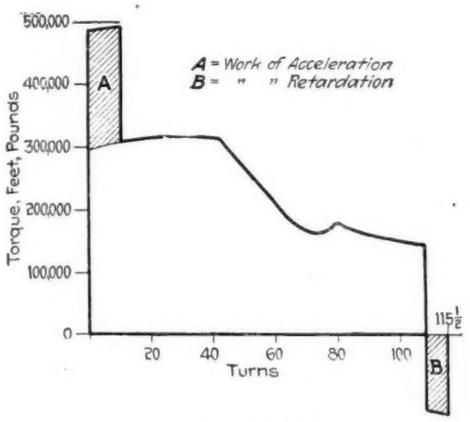


FIG. 5. TORQUE DIAGRAM

With the condensing equipment the unit has a total weight of 1,765,000 lb. A few of the leading dimensions follow: Drum diameter, ft., 30; steam cylinders, in., 32 x 60 x 66; main bearings, in., 28 x 54; crank pins, length and diameter, in., 15 x 15½; crosshead pins, in., 8 x 12; piston rod, h.p. diameter, in., 6; piston rod, l.p. diameter, in., 10; weight of skip, lb., 10,000; weight of 10,000 ft. of 1⅝-in. rope, lb., 41,500; time required for one trip of 10,000 ft., 4 min. 8 sec.

The hoist is housed in a substantial steel-reinforced concrete building which is the most modern structure of its kind in the district. The engine covers a floor space of 60 x 54 ft. and stands 60 ft. high from the bottom of the foundation to the top of the drum, the foundation under the hoist and condensing equipment containing 3,000 yd. of concrete. The hoist is a magnificent piece of machinery and constitutes another notable monument to Nordberg genius.

To get out as much copper ore as possible from a great depth, the hoist is of mammoth proportions, and to secure the highest economy, it was designed to operate compound condensing. Speaking generally, a properly designed compound condensing hoist will consume only 50 to 60 per cent of the steam used by duplex Corliss hoists and only 20 to 30 per cent of the steam used by a slide-valve hoist. With the long travel in the present case and the large amount of power required, and particularly with the present scarcity and high price of coal,

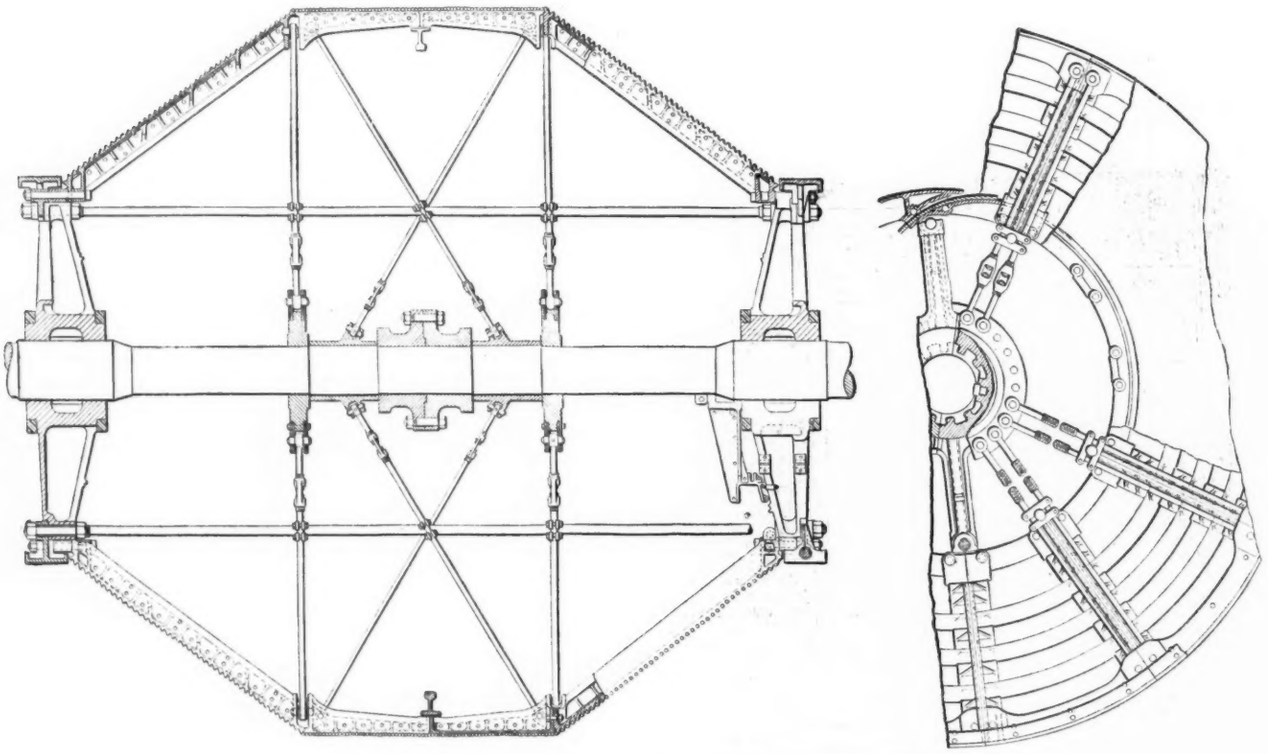

FIG. 6. SECTIONAL VIEW THROUGH DRUM SHOWING STEEL TENSION RODS

condensing operation will bring returns well worth while on the additional investment.

With cylinders 32 and 60 by 66 in. the hoist is to operate in balance at a maximum speed of about 34 r.p.m. and with 160 lb. maximum boiler pressure. Two skips operate on an incline of from 54 deg. at the top to 36 deg. at the bottom, and as the shaft extends it is probable that the angle of incline will gradually lessen. The winding capacity of the hoist to be utilized for the present is 10,000 ft. of $1\frac{3}{8}$-in. rope, reaching down the inclined shaft to a vertical depth of 6,600 ft. This much of the rope is wound in a single layer on one conical end and the middle section of the drum.

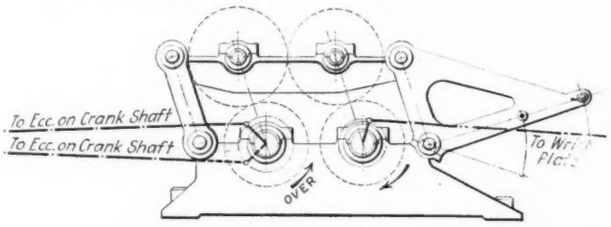


FIG. 7. DIAGRAM OF FOUR GEAR REVERSE

As the shaft deepens, there is additional capacity for 3,300 ft. of rope on the other conical end of the drum, thus giving a maximum haul of 13,300 ft., reaching to a vertical depth of 8,600 ft. The load carried per trip is 20,000 lb. of rock, the rope speed being 3,200 ft. per min., or $53\frac{1}{3}$ ft. per sec., as indicated in Fig. 4. At the maximum travel mentioned the load will be somewhat less.

As the hoist must run with equal facility in either direction, the reversing gear must give exactly the same motion when the engine is running over or under. As this cannot be accomplished by any link motion, the Nordberg four-gear reverse shown in Fig. 7 is used. Of the four spur gears one is driven by parallel rods and cranks from the mainshaft. This gear drives a second and this in turn a third gear, and the third a fourth, and the last gear, which is keyed on a shaft that is parallel to the mainshaft and extends between the two engine frames. At the end of the shaft are placed the cranks that give motion to the wristplates on the cylinder. The centers of the four gears mentioned form the four corners of a parallelogram. The second and third are operated by an oil cylinder which causes the circumference of the fourth gear, and with it the shaft to which it is keyed, to advance or retard in relation to the position of the cranks, the effect being the same as if the eccentrics were set forward or back on the engine shaft. This type of reversing gear has the advantage that its action causes the wristplate to move through its entire range of motion, meaning that the valves can always be picked up at any time, a feature that is not possessed by any link-motion reversing gear.

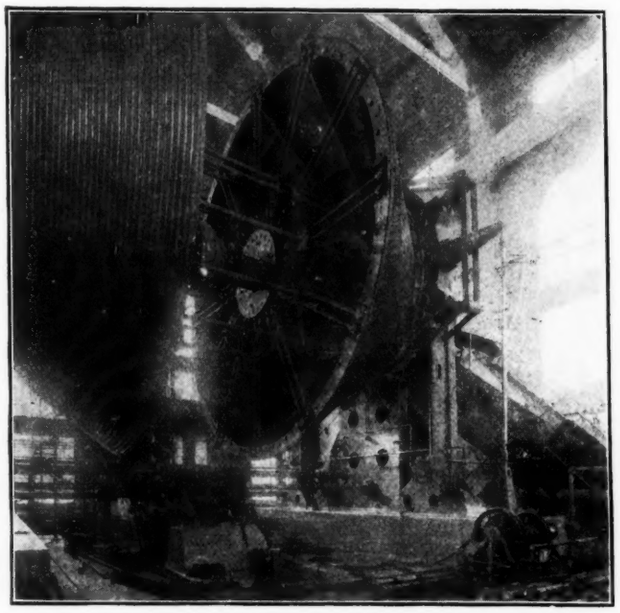

FIG. 8. INTERIOR OF DRUM BEFORE MIDDLE SECTION OF SHELL WAS ASSEMBLED

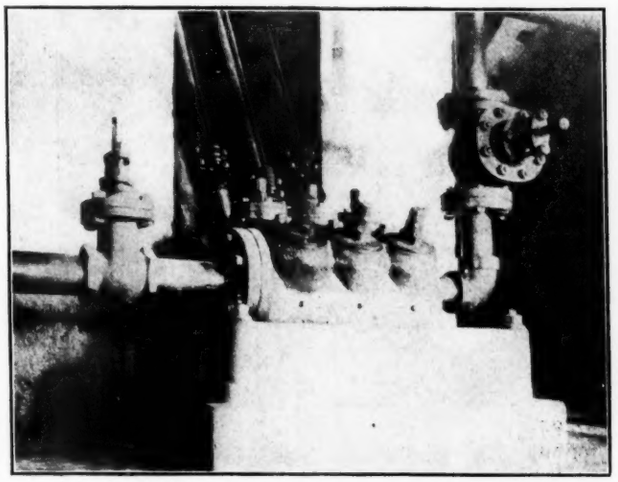

FIG. 9. TRIPLEX OIL PUMP SERVICE ACCUMULATOR

Reference to Fig. 6 will show that the drum is of the cylindro-conical type so familiar to the Lake Superior copper district. The conical ends tend to equalize the torque on the engine throughout the trip. The outer diameters are 16 ft. and the diameter of the middle section 30 ft. The length is also 30 ft. and the total weight without the shaft, 516,000 lb. With a drum of such great mass and eight impulses per revolution, pulsation of the rope is practically eliminated. The conical ends of the drum tend to even up the torque on the engine. A torque diagram is shown in Fig. 5.

Support for the drum is provided by two end spiders, where the load is concentrated adjacent to the main bearings so that shaft deflection is reduced to a minimum. The drum itself is designed as a bridge truss with steel tension rods, distortion being prevented by radial rods attached to central rings which float on the shaft.

The shell of the drum is made up of cast iron in forty-eight pieces, securely bolted together and held as one solid unit by the tierods. Tightening the turnbuckles on the radial rods puts the drum in compression rather than tension, so that any tensile strain is taken by the rods rather than by the cast-iron shell. Tightening of these radial rods tends to push down on the tapered portion of the shell and outward on the supporting spiders. Long tierods parallel to the shaft hold the spiders together and resist this tilting action.

At the central portion of the drum diagonal rods secured to the shell take the deflection out of the shaft caused by its own weight in a span of nearly 30 ft. between spiders. As this portion of the shaft does not bear the weight of the drum and by means of the diagonal rods is itself supported, its cross-section is therefore reduced. The joint at the center of the shaft

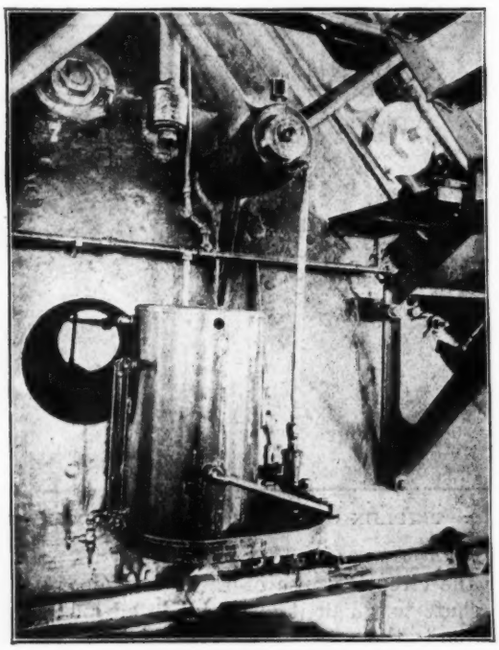

FIG. 10. FILTER AND PUMP FOR BEARING OIL

was made for convenience of assembly. At each end of the main drum is a take-up drum equipped with rope clamps. Long-radius spouts lead the rope to the drum grooves.

At either end of the drum is an enormous brake, 16 ft. in diameter, of the parallel-motion post type. The brake-shoe blocks are made of wood and the brake posts of cast iron reinforced with steel links to remove the tension strain from the casting. The brakes are of the gravity type applied by a fixed weight and released by a set of thrust cylinders in which oil is used under pressure.

As may be inferred from Fig. 2, the ends of the brake carriers form the corners of a parallelogram such that the brake post must move in a position parallel to itself. There are two sets of levers and drawbars for drawing the brakes together, one at the top and one at the bottom, with turnbuckles provided for adjustment. With this construction a brake shoe has the same pressure around the circumference, so that there is no uneven wear or pinching, and a small movement clears the brake.

### Operation of the Hydraulic Thrust Cylinders

Operation of the reverse and throttles as well as of the brakes is effected by hydraulic thrust cylinders, the motive power being oil under pressure furnished by a triplex pump and an accumulator. Oil is admitted to and exhausted from these thrust cylinders by balanced hydraulic valves constructed so that it is impossible for the inlet and exhaust valves to be open at the same time. The hydraulic valves are operated from the operating platform by a system of floating levers, the arrangement of the mechanism being such that the movement of the hydraulic valves and therefore the thrust cylinder follows the motion of the operator's lever. Whenever the operator's lever comes to rest, the thrust cylinder also comes to rest and is locked in that position owing to the fact that both hydraulic valves are closed. In this way the operator has full control over the mechanism the same as he would by direct hand operation of the brakes and the throttles. To prevent oil hammer each thrust cylinder is provided with an air chamber next to the valves.

### Safety Stop Protection

Protection is afforded the hoist by a safety stop, whereby the throttle valve is automatically closed as the skip approaches the landing. In case of overwinding the brakes are applied automatically and the control is arranged so that the hoist cannot be started in the wrong direction by the operator. Overspeed is prevented by a flyball governor especially designed for hoisting-engine service to control the cutoff cams of the valve gear. An arrangement is made whereby the proper dashpots can be hooked up by throwing the reverse mechanism over and back from one position to the other.

As usual the accumulator is of the direct-pressure loaded plunger type consisting of a fixed sleeve and a removable plunger to which a bucket is attached. A sump is provided into which all the oil used by the operating cylinders is returned and from which the triplex pump draws its supply. This pump, Fig. 9, is driven by means of eccentrics on the shaft of the Corliss engine driving the condenser auxiliaries. A bypass valve is provided, which is operated by the moving

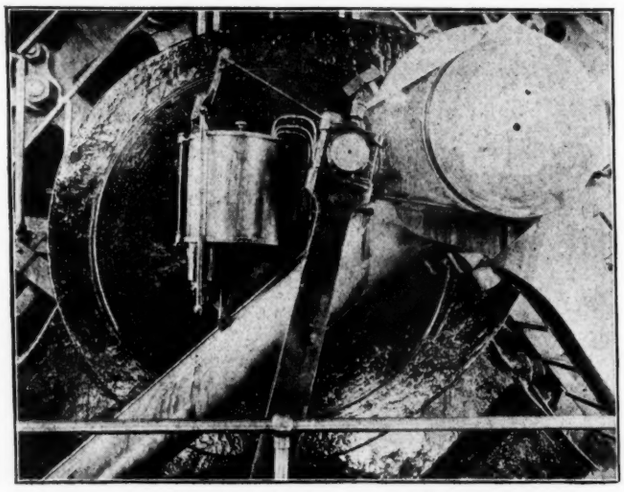

FIG. 11. OIL PUMP FOR LUBRICATION OF CRANK AND CROSSHEAD PINS

element of the accumulator, so that when the latter reaches the top of its travel, the oil furnished by the pump will be returned directly back into the sump and used again.

Lubrication of the four cylinders of the hoist and of the main bearings is standard. Each cylinder has its mechanical oil pump driven from the valve gear, and lubrication of the bearings is effected by a filtering system through which the oil is continuously circulated. By means of a vertical single-plunger pump, driven

from the engine, as in Fig. 10, the bearings are flooded with oil. The overflow gravitates to the filter and is again taken by the pump to be forced back to the bearings. The process is continuous.

Lubrication of the crank and crosshead pins is special. It is supplied by three-feed plunger pumps, one on the crank end of each connecting rod, as shown in Fig. 11. Each pump derives its motion from the other rod on the same pin, the relative movement between the ends of the rods producing a small oscillating motion which actuates the three plungers, attached to a common crosshead underneath the pump. The three single-cylinder pumps are immersed in an oil tank of comparatively large size. From the tank, oil is admitted into the pump cylinders, which are ¼ in. in diameter, through openings in the cylinder wall spaced near the end of the stroke. A sliding sleeve is made to uncover the inlet ports at a greater or less distance from the ends of the cylinders, regulating in this way the quantity of oil to be supplied. Adjustment of this sleeve is effected by a screw rod rising to the outside of the tank.

### Counter-Current Type of Jet Condenser Used

Exhaust steam from the hoisting engine is discharged into a counter-current jet-type condenser, Fig. 12, consisting of a drum 8 ft. in diameter and 17 ft. long, receiving exhaust steam at one end and the injection water at the top of the opposite end. The drum is slightly inclined from the horizontal and is provided with a number of trays in series, over which the incoming water flows to encounter the steam entering at the lower end of the drum. This construction provides the large surface and the great body of water required to maintain a vacuum during peak periods, such as at starting, when the volume of steam will be greater than usual.

Nozzles are arranged so that the air may be drawn off from the high end and water from the low end of the condenser. An automatic vacuum-breaking device protects the engine cylinders. The illustration, Fig. 12, shows the path the water takes from one tray to another.

Condenser auxiliaries consist of a pair of 24 x 12-in. single-acting vertical circulating pumps and a 22 x 36-in. dry-air pump of the horizontal type driven in tandem by a 14 x 36-in. Corliss engine cylinder. The vertical circulating pumps are set below the floor and are driven from the tail rod of the air pump by means of a bell-crank connection, with a sliding block in a slot taking care of the arc of travel the movement of the pump plunger being up and down.

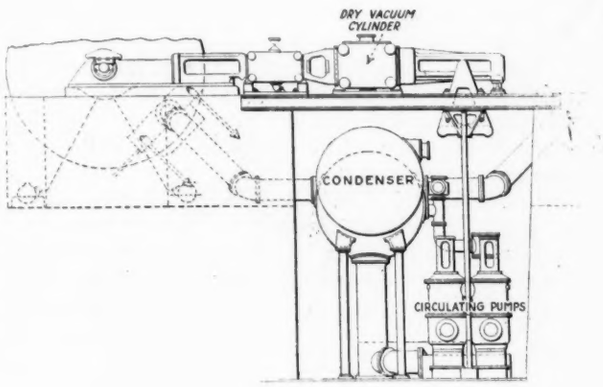


FIG. 13. ELEVATION SHOWING CONDENSER AND AUXILIARY EQUIPMENT

Although the official test on the big hoist has not been conducted, a rough estimate places the amount of steam utilized per trip of 10,000 ft. at 1,460 lb. The condenser is designed to take care of this amount of steam, and it receives exhaust only from the hoist as the condenser auxiliaries exhaust to the feed-water heater. On the assumption of twelve trips per hour, the steam consumption would be 17,520 lb., and at 10 tons per trip, a total of 120 tons of rock would be hoisted. On this basis, per ton of rock hoisted, the engine would be using 146 lb. of steam and 1.460 pounds per trip.

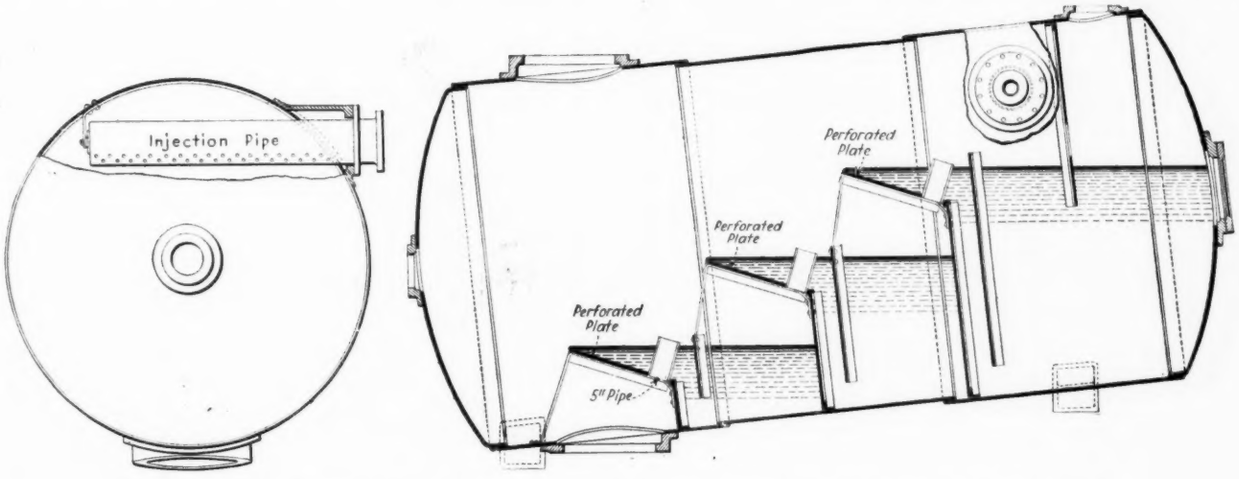


FIG. 12. COUNTER-CURRENT JET CONDENSER WITH TRAYS EMPLOYED TO INCREASE THE AMOUNT OF COOLING SURFACE

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In grinding admission and exhaust valves, use a coarse grinding compound first, following this with a fine grade of compound. A ground surface ⅛-in. wide is amply large. Too much grinding will cause the surfaces to convex.

# Temperature and Pressure Tables for Saturated Ammonia

NEW temperature and pressure tables for saturated ammonia are reproduced here. These tables, which were prepared by the United States Bureau of Standards were presented before the annual meeting of the American Society of Refrigeration Engineers. They are tentative, but it is not likely that any serious changes will be made. The errors, if any, will cover only the last decimal place.

The final tables, which will include the data for superheated ammonia, will not appear for some time. The preparation of these tables has entailed years of labor and much development of new testing apparatus.

TABLE I. SATURATED AMMONIA: TEMPERATURE TABLE

| Temp. F. | Pres. Lb. per Sq.In. | Spec. Vol. Cu.Ft. per Lb. Liquid | Spec. Vol. Cu.Ft. per Lb. Vapor | Total Heat of Liquid | Latent Heat of Evap. | Total Heat of Vapor | Entropy Liquid | Entropy Evap. | Entropy Vapor |
|---|---|---|---|---|---|---|---|---|---|
| — 40 | 10.41 | 0.02322 | 24.84 | 0.0 | 597.0 | 597.0 | 0.000 | 1.423 | 1.423 |
| — 39 | 10.72 | 0.02324 | 24.16 | 1.1 | 596.3 | 597.4 | 0.002 | 1.418 | 1.420 |
| — 38 | 11.04 | 0.02326 | 23.50 | 2.1 | 595.6 | 597.7 | 0.005 | 1.413 | 1.418 |
| — 37 | 11.37 | 0.02328 | 22.87 | 3.2 | 595.0 | 598.2 | 0.008 | 1.408 | 1.416 |
| — 36 | 11.71 | 0.02331 | 22.25 | 4.3 | 594.3 | 598.6 | 0.010 | 1.403 | 1.413 |
| — 35 | 12.05 | 0.02333 | 21.66 | 5.3 | 593.6 | 598.9 | 0.013 | 1.398 | 1.411 |
| — 34 | 12.41 | 0.02335 | 21.09 | 6.4 | 592.9 | 599.3 | 0.015 | 1.393 | 1.408 |
| — 33 | 12.77 | 0.02338 | 20.53 | 7.5 | 592.3 | 599.8 | 0.018 | 1.388 | 1.406 |
| — 32 | 13.14 | 0.02340 | 19.99 | 8.5 | 591.6 | 600.1 | 0.020 | 1.384 | 1.404 |
| — 31 | 13.52 | 0.02342 | 19.46 | 9 6 | 590.9 | 600.5 | 0.023 | 1.379 | 1.402 |
| — 30 | 13.91 | 0.02345 | 18.96 | 10.7 | 590.2 | 600.9 | 0.025 | 1.374 | 1.399 |
| — 29 | 14.30 | 0.02347 | 18.46 | 11.7 | 589.5 | 601.2 | 0.028 | 1.369 | 1.397 |
| — 28 | 14.71 | 0.02349 | 17.99 | 12.8 | 588.8 | 601.6 | 0.030 | 1.364 | 1.394 |
| — 27 | 15.12 | 0.02352 | 17.52 | 13.9 | 588.1 | 602.0 | 0.033 | 1.360 | 1.393 |
| — 26 | 15.55 | 0.02354 | 17.08 | 14.9 | 587.5 | 602.4 | 0.035 | 1.355 | 1.390 |
| — 25 | 15.98 | 0.02357 | 16.64 | 16.0 | 586.8 | 602.8 | 0.037 | 1.350 | 1.387 |
| — 24 | 16.42 | 0.02359 | 16.22 | 17.1 | 586.1 | 603.2 | 0.040 | 1.346 | 1.386 |
| — 23 | 16.88 | 0.02361 | 15.81 | 18.1 | 585.4 | 603.5 | 0.042 | 1.341 | 1.383 |
| — 22 | 17.34 | 0.02364 | 15.42 | 19.2 | 584.7 | 603.9 | 0.045 | 1.336 | 1.381 |
| — 21 | 17.81 | 0.02366 | 15.04 | 20.3 | 584.0 | 604.3 | 0.047 | 1.332 | 1.379 |
| — 20 | 18.30 | 0.02369 | 14.67 | 21.4 | 583.3 | 604.7 | 0.050 | 1.327 | 1.377 |
| — 19 | 18.79 | 0.02371 | 14.31 | 22.4 | 582.6 | 605.0 | 0.052 | 1.322 | 1.374 |
| — 18 | 19.30 | 0.02374 | 13.96 | 23.5 | 581.9 | 605.4 | 0.055 | 1.318 | 1.373 |
| — 17 | 19.81 | 0.02376 | 13.62 | 24.6 | 581.1 | 605.7 | 0.057 | 1.313 | 1.370 |
| — 16 | 20.34 | 0.02378 | 13.29 | 25.6 | 580.4 | 606.0 | 0.059 | 1.308 | 1.367 |
| — 15 | 20.88 | 0.02381 | 12.97 | 26.7 | 579.7 | 606.4 | 0.062 | 1.304 | 1.366 |
| — 14 | 21.43 | 0.02383 | 12.66 | 27.8 | 579.0 | 606.8 | 0.064 | 1.299 | 1.363 |
| — 13 | 21.99 | 0.02386 | 12.36 | 28.9 | 578.3 | 607.2 | 0.067 | 1.295 | 1.362 |
| — 12 | 22.56 | 0.02388 | 12.06 | 29.9 | 577.6 | 607.5 | 0.069 | 1.290 | 1.359 |
| — 11 | 23.15 | 0.02391 | 11.78 | 31.0 | 576.8 | 607.8 | 0.071 | 1.286 | 1.357 |
| — 10 | 23.75 | 0.02393 | 11.50 | 32.1 | 576.1 | 608.2 | 0.074 | 1.281 | 1.355 |
| — 9 | 24.35 | 0.02396 | 11.23 | 33.2 | 575.4 | 608.6 | 0.076 | 1.277 | 1.353 |
| — 8 | 24.98 | 0.02399 | 10.97 | 34.3 | 574.6 | 608.9 | 0.078 | 1.272 | 1.350 |
| — 7 | 25.61 | 0.02401 | 10.71 | 35.3 | 573.9 | 609.2 | 0.081 | 1.268 | 1.349 |
| — 6 | 26.26 | 0.02404 | 10.46 | 36.4 | 573.2 | 609.6 | 0.083 | 1.264 | 1.347 |
| — 5 | 26.92 | 0.02406 | 10.22 | 37.5 | 572.4 | 609.9 | 0.086 | 1.259 | 1.345 |
| — 4 | 27.59 | 0.02409 | 9.99 | 38.6 | 571.7 | 610.3 | 0.088 | 1.255 | 1.344 |
| — 3 | 28.28 | 0.02411 | 9.76 | 39.7 | 570.9 | 610 6 | 0.090 | 1.250 | 1.340 |
| — 2 | 28.98 | 0.02414 | 9.54 | 40.7 | 570.2 | 610 9 | 0.093 | 1.246 | 1.339 |
| — 1 | 29.69 | 0.02417 | 9.32 | 41.8 | 569.4 | 611.2 | 0.095 | 1.242 | 1.337 |
| 0 | 30.42 | 0.02419 | 9.114 | 42.9 | 568.7 | 611.6 | 0.097 | 1.237 | 1.33 |
| 1 | 31.16 | 0.02422 | 8.911 | 44.0 | 567.9 | 611.9 | 0.100 | 1.233 | 1.33 |
| 2 | 31.92 | 0.02424 | 8.712 | 45.1 | 567.2 | 612.3 | 0.102 | 1.229 | 1.33 |
| 3 | 32.69 | 0.02427 | 8.520 | 46.2 | 566.4 | 612.6 | 0.104 | 1.224 | 1.32 |
| 4 | 33.48 | 0.02430 | 8.332 | 47.2 | 565.7 | 612.9 | 0.107 | 1.220 | 1.32 |
| 5 | 34.28 | 0.02432 | 8.149 | 48.3 | 564.9 | 613.2 | 0.109 | 1.216 | 1.32 |
| 6 | 35.09 | 0.02435 | 7.971 | 49.4 | 564.1 | 613.5 | 0.112 | 1.212 | 1.324 |
| 7 | 35.92 | 0.02438 | 7.797 | 50.5 | 563.3 | 613.8 | 0.114 | 1.207 | 1.321 |
| 8 | 36.77 | 0.02440 | 7.628 | 51.6 | 562.6 | 614.2 | 0.116 | 1.203 | 1.319 |
| 9 | 37.63 | 0.02443 | 7.464 | 52.7 | 561.8 | 614.5 | 0.119 | 1.199 | 1.318 |
| 10 | 38.51 | 0.02446 | 7.304 | 53.8 | 561.0 | 614.8 | 0.121 | 1.195 | 1.316 |
| 11 | 39.40 | 0.02449 | 7.148 | 54.9 | 560.2 | 615.1 | 0.123 | 1.191 | 1.314 |
| 12 | 40.31 | 0.02451 | 6.996 | 56.0 | 559.5 | 615.5 | 0.125 | 1.186 | 1.311 |
| 13 | 41.24 | 0.02454 | 6.847 | 57.0 | 558.7 | 615.7 | 0.122 | 1.182 | 1.310 |
| 14 | 42.19 | 0.02457 | 6.703 | 58.1 | 557.9 | 616.0 | 0.130 | 1.178 | 1.308 |
| 15 | 43.15 | 0.02460 | 6.562 | 59.2 | 557.1 | 616.3 | 0.132 | 1.174 | 1.306 |
| 16 | 44.12 | 0.02462 | 6.425 | 60.3 | 556.3 | 616.6 | 0.135 | 1.170 | 1.305 |
| 17 | 45.12 | 0.02465 | 6.291 | 61.4 | 555.5 | 616.9 | 0.137 | 1.166 | 1.303 |
| 18 | 46.13 | 0.02468 | 6.161 | 62.5 | 554.7 | 617.2 | 0.139 | 1.161 | 1.300 |
| 19 | 47.16 | 0.02471 | 6.034 | 63.6 | 553.9 | 617.5 | 0.141 | 1.157 | 1.298 |
| 20 | 48.21 | 0.02474 | 5.910 | 64.7 | 553.1 | 617.8 | 0.144 | 1.153 | 1.297 |
| 21 | 49.28 | 0.02476 | 5.789 | 65.8 | 552.3 | 618.1 | 0.146 | 1.149 | 1.295 |
| 22 | 50.36 | 0.02479 | 5.672 | 66.9 | 551.5 | 618.4 | 0.148 | 1.145 | 1.293 |
| 23 | 51.47 | 0.02482 | 5.557 | 68.0 | 550.7 | 618.7 | 0.151 | 1.141 | 1.292 |
| 24 | 52.59 | 0.02485 | 5.445 | 69.1 | 549.9 | 619.0 | 0.153 | 1.137 | 1.290 |
| 25 | 53.73 | 0.02488 | 5.336 | 70.2 | 549.1 | 619.3 | 0.155 | 1.133 | 1.288 |
| 26 | 54.90 | 0.02491 | 5.230 | 71.3 | 548.2 | 619.5 | 0.157 | 1.129 | 1.286 |
| 27 | 56.08 | 0.02494 | 5.126 | 72.4 | 547.4 | 619.8 | 0.160 | 1.125 | 1.285 |
| 28 | 57.28 | 0.02497 | 5.024 | 73.5 | 546.6 | 620.1 | 0.162 | 1.121 | 1.283 |
| 29 | 58.50 | 0.02500 | 4.925 | 74.6 | 545.8 | 620.4 | 0.164 | 1.117 | 1.281 |

TABLE I. (Continued)

| Temp. F. | Pres. Lb.per Sq.In. | Spec. Vol. Cu.Ft. per Lb. Liquid | Spec. Vol. Cu.Ft. per Lb. Vapor | Total Heat of Liquid | Latent Heat of Evap. | Total Heat of Vapor | Entropy Liquid | Entropy Evap. | Entropy Vapor |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 59.74 | 0.02503 | 4.827 | 75.7 | 544.9 | 620.6 | 0.166 | 1.113 | 1.279 |
| 31 | 61.00 | 0.02505 | 4.733 | 76.8 | 544.1 | 620.9 | 0.169 | 1.109 | 1.278 |
| 32 | 62.28 | 0.02508 | 4.640 | 77.9 | 543.3 | 621.2 | 0.171 | 1.105 | 1.276 |
| 33 | 63.58 | 0.02511 | 4.550 | 79.0 | 542.4 | 621.4 | 0.173 | 1.101 | 1.274 |
| 34 | 64.91 | 0.02514 | 4.462 | 80.1 | 541.6 | 621.7 | 0.175 | 1.097 | 1.272 |
| 35 | 66.26 | 0.02518 | 4.375 | 81.2 | 540.7 | 621.9 | 0.177 | 1.093 | 1.270 |
| 36 | 67.62 | 0.02521 | 4.291 | 82.3 | 539.9 | 622.2 | 0.180 | 1.089 | 1.269 |
| 37 | 69.01 | 0.02524 | 4.209 | 83.4 | 539.0 | 622.4 | 0.182 | 1.085 | 1.267 |
| 38 | 70.43 | 0.02527 | 4.129 | 84.6 | 538.2 | 622.8 | 0.184 | 1.082 | 1.266 |
| 39 | 71.86 | 0.02530 | 4.650 | 85.7 | 537.3 | 523.0 | 0.186 | 1.078 | 1.264 |
| 0 | 73.32 | 0.02533 | 3.974 | 86.8 | 536.5 | 623.3 | 0.189 | 1.074 | 1.263 |
| 1 | 74.80 | 0.02536 | 3.899 | 87.9 | 535.6 | 623.5 | 0.191 | 1.070 | 1.267 |
| 2 | 76.30 | 0.02539 | 3.826 | 89.0 | 534.7 | 623.7 | 0.193 | 1.066 | 1.259 |
| 43 | 77.83 | 0.02542 | 3.754 | 90.1 | 533.8 | 623.9 | 0.195 | 1.062 | 1.257 |
| 44 | 79.38 | 0.02545 | 3.684 | 91.2 | 533.0 | 624.2 | 0.197 | 1.058 | 1.255 |
| 45 | 80.95 | 0.02548 | 3.616 | 92.3 | 532.1 | 624.4 | 0.200 | 1.054 | 1.254 |
| 46 | 82.55 | 0.02551 | 3.549 | 93.5 | 531.2 | 624.7 | 0.202 | 1.051 | 1.253 |
| 47 | 84.17 | 0.02555 | 3.484 | 94.6 | 530.3 | 624.9 | 0.204 | 1.047 | 1.251 |
| 48 | 82.82 | 0.02558 | 3.420 | 95.7 | 529.5 | 625.2 | 0.206 | 1.043 | 1.249 |
| 49 | 87.49 | 0.02561 | 3.357 | 96.8 | 528.6 | 625.4 | 0.208 | 1.039 | 1.247 |
| 50 | 89.19 | 0.02564 | 3.296 | 97.9 | 527.7 | 625.6 | 0.211 | 1.036 | 1.247 |
| 51 | 90.91 | 0.02568 | 3.236 | 99.0 | 526.8 | 625.8 | 0.213 | 1.032 | 1.245 |
| 52 | 92.66 | 0.02571 | 3.178 | 100.2 | 525.9 | 626.1 | 0.215 | 1.028 | 1.245 |
| 53 | 94.43 | 0.02574 | 3.121 | 101.3 | 524.9 | 626.2 | 0.217 | 1.024 | 1.241 |
| 54 | 96.23 | 0.02577 | 3.065 | 102.4 | 524.0 | 626.4 | 0.219 | 1.020 | 1.239 |
| 55 | 98.05 | 0.02581 | 3.010 | 103.5 | 523.1 | 626.6 | 0.221 | 1.017 | 1.239 |
| 56 | 99.91 | 0.02584 | 2.957 | 104.7 | 522.2 | 626.9 | 0.224 | 1.013 | 1.23 |
| 57 | 101.8 | 0.02587 | 2.904 | 105.8 | 521.2 | 627.0 | 0.226 | 1.009 | 1.23 |
| 58 | 103.7 | 0.02590 | 2.853 | 106.9 | 520.3 | 627.2 | 0.228 | 1.005 | 1.233 |
| 59 | 105.6 | 0.02594 | 2.803 | 108.0 | 519.4 | 627.4 | 0.230 | 1.002 | 1.232 |
| 60 | 107.6 | 0.02597 | 2.754 | 109.2 | 518.5 | 627.7 | 0.232 | 0.998 | 1.232 |
| 61 | 109.6 | 0.02601 | 2.706 | 110.3 | 517.5 | 627.8 | 0.234 | 0.994 | 1.220 |
| 62 | 111.6 | 0.02604 | 2.658 | 111.4 | 516.6 | 628.0 | 0.237 | 0.990 | 1.228 |
| 63 | 113.6 | 0.02608 | 2.612 | 112.6 | 515.6 | 628.2 | 0.239 | 0.987 | 1.2 5 |
| 64 | 115.7 | 0.02611 | 2.567 | 113.7 | 514.7 | 628.4 | 0.241 | 0.983 | 1.224 |
| 65 | 117.8 | 0.02614 | 2.522 | 114.8 | 513.7 | 628.5 | 0.243 | 0.979 | 1.227 |
| 66 | 120.0 | 0.02618 | 2.479 | 116.0 | 512.8 | 628.8 | 0.245 | 0.976 | 1.222 |
| 67 | 122.1 | 0.02621 | 2.436 | 117.1 | 511.8 | 628.9 | 0.247 | 0.972 | 1.219 |
| 68 | 124.3 | 0.02625 | 2.394 | 118.2 | 510.9 | 629.1 | 0.249 | 0.958 | 1.217 |
| 69 | 126.5 | 0.02628 | 2.354 | 119.4 | 509.9 | 629.3 | 0.251 | 0.965 | 1.216 |
| 70 | 128.8 | 0.02632 | 2.314 | 120.5 | 508.9 | 629.4 | 0.254 | 0.961 | 1.215 |
| 71 | 131.1 | 0.02635 | 2.275 | 121.7 | 508.0 | 629.7 | 0.256 | 0.957 | 1.212 |
| 72 | 133.4 | 0.02639 | 2.236 | 122.8 | 507.0 | 629.8 | 0.258 | 0.954 | 1.212 |
| 73 | 135.7 | 0.02643 | 2.199 | 123.9 | 506.0 | 629.9 | 0.260 | 0.950 | 1.210 |
| 74 | 138.1 | 0.02646 | 2.162 | 125.1 | 505.0 | 630.1 | 0.262 | 0.946 | 1.208 |
| 75 | 140.5 | 0.02650 | 2.126 | 126.2 | 504.1 | 630.3 | 0.264 | 0.943 | 1.207 |
| 76 | 143.0 | 0.02653 | 2.091 | 127.4 | 503.1 | 630.5 | 0.266 | 0.939 | 1.205 |
| 77 | 145.4 | 0.02657 | 2.056 | 128.5 | 502.1 | 630.6 | 0.268 | 0.936 | 1.204 |
| 78 | 147.9 | 0.02661 | 2.022 | 129.7 | 501.1 | 630.8 | 0.271 | 0.932 | 1.203 |
| 79 | 150.5 | 0.02664 | 1.989 | 130.8 | 500.1 | 630.9 | 0.273 | 0.929 | 1.202 |
| 0 | 153.1 | 0.02668 | 1.956 | 132.0 | 499.1 | 631.1 | 0.275 | 0.925 | 1.200 |
| 1 | 155.7 | 0.02672 | 1.924 | 133.1 | 498.1 | 631.2 | 0.277 | 0.921 | 1.198 |
| 2 | 158.3 | 0.02675 | 1.893 | 134.3 | 497.0 | 631.3 | 0.279 | 0.918 | 1.197 |
| 3 | 161.0 | 0.02679 | 1.862 | 135.4 | 496.0 | 631.4 | 0.281 | 0.914 | 1.195 |
| 84 | 163.7 | 0.02684 | 1.832 | 136.6 | 495.0 | 631.6 | 0.283 | 0.911 | 1.194 |
| 85 | 166.4 | 0.02687 | 1.803 | 137.7 | 494.0 | 631.7 | 0.285 | 0.907 | 1.192 |
| 86 | 169.2 | 0.02691 | 1.774 | 138.9 | 493.0 | 631.0 | 0.287 | 0.904 | 1.191 |
| 87 | 172.0 | 0.02695 | 1.745 | 140.0 | 491.9 | 631.9 | 0.289 | 0.900 | 1.189 |
| 88 | 174.8 | 0.02699 | 1.717 | 141.2 | 490.9 | 632.1 | 0.292 | 0.896 | 1.188 |
| 89 | 177.7 | 0.02703 | 1.690 | 142.3 | 489.8 | 632.1 | 0.294 | 0.893 | 1.187 |
| 90 | 180.7 | 0.02707 | 1.663 | 143.5 | 488.8 | 632.3 | 0.296 | 0.889 | 1.185 |
| 91 | 183.6 | 0.02711 | 1.637 | 144.7 | 487.7 | 632.4 | 0.298 | 0.886 | 1.184 |
| 92 | 186.6 | 0.02715 | 1.611 | 145.8 | 485.7 | 632.5 | 0.300 | 0.882 | 1.182 |
| 93 | 189.6 | 0.02719 | 1.585 | 147.0 | 485.6 | 632.6 | 0.302 | 0.879 | 1.181 |
| 94 | 192.7 | 0.02723 | 1.560 | 148.2 | 484.6 | 632.8 | 0.304 | 0.875 | 1.179 |
| 95 | 195.8 | 0.02727 | 1.536 | 149.3 | 483.5 | 632.8 | 0.306 | 0.872 | 1.178 |
| 96 | 198.9 | 0.02731 | 1.511 | 150.5 | 482.4 | 632.9 | 0.308 | 0.868 | 1.176 |
| 97 | 202.1 | 0.02735 | 1.488 | 151.7 | 481.3 | 633.0 | 0.310 | 0.865 | 1.175 |
| 98 | 205.3 | 0.02739 | 1.464 | 152.8 | 480.2 | 633.0 | 0.312 | 0.861 | 1.173 |
| 99 | 208.6 | 0.02743 | 1.442 | 154.0 | 479.1 | 633.1 | 0.314 | 0.858 | 1.172 |
| 100 | 211.9 | 0.02747 | 1.419 | 155.2 | 478.0 | 633.2 | 0.316 | 0.854 | 1.170 |
| 101 | 215.2 | 0.02752 | 1.398 | 156.4 | 476.9 | 633.3 | 0.319 | 0.851 | 1.170 |
| 102 | 218.6 | 0.02756 | 1.376 | 157.5 | 475.8 | 633.3 | 0.321 | 0.847 | 1.168 |
| 103 | 222.0 | 0.02760 | 1.355 | 158.7 | 474.7 | 633.4 | 0.323 | 0.844 | 1.167 |
| 104 | 225.4 | 0.02764 | 1.334 | 159.9 | 473.6 | 633.5 | 0.325 | 0.840 | 1.165 |
| 105 | 228.9 | 0.02769 | 1.314 | 161.1 | 472.5 | 633.6 | 0.327 | 0.837 | 1.164 |
| 106 | 232.5 | 0.02773 | 1.294 | 162.2 | 471.4 | 633.6 | 0.329 | 0.833 | 1.162 |
| 107 | 236.0 | 0.02777 | 1.274 | 163.4 | 470.2 | 633.6 | 0.331 | 0.830 | 1.161 |
| 108 | 239.7 | 0.02782 | 1.255 | 164.6 | 469.0 | 633.6 | 0.333 | 0.826 | 1.159 |
| 109 | 243.3 | 0.02786 | 1.236 | 165.8 | 467.9 | 633.7 | 0.335 | 0.823 | 1.158 |
| 110 | 247.0 | 0.02790 | 1.217 | 167.0 | 466.7 | 633.7 | 0.337 | 0.819 | 1.156 |
| 111 | 250.8 | 0.02795 | 1.199 | 168.2 | 465.6 | 633.8 | 0.339 | 0.816 | 1.155 |
| 112 | 254.5 | 0.02799 | 1.181 | 169.4 | 464.4 | 633.8 | 0.341 | 0.813 | 1.154 |
| 113 | 258.4 | 0.02804 | 1.163 | 170.5 | 463.3 | 633.8 | 0.343 | 0.809 | 1.152 |
| 114 | 262.2 | 0.02808 | 1.146 | 171.8 | 462.1 | 633.9 | 0.345 | 0.806 | 1.151 |
| 115 | 266.1 | 0.02813 | 1.129 | 173.0 | 460.9 | 633.9 | 0.347 | 0.802 | 1.149 |
| 116 | 270.1 | 0.02817 | 1.112 | 174.2 | 459.7 | 633.9 | 0.349 | 0.799 | 1.148 |
| 117 | 274.1 | 0.02822 | 1.095 | 175.4 | 458.5 | 633.9 | 0.351 | 0.795 | 1.146 |
| 118 | 278.2 | 0.02827 | 1.079 | 176.6 | 457.3 | 633.9 | 0.353 | 0.792 | 1.145 |
| 119 | 282.3 | 0.02832 | 1.063 | 177.8 | 456.1 | 633.9 | 0.355 | 0.788 | 1.943 |
| 120 | 286.4 | 0.02836 | 1.048 | 179.0 | 454.9 | 633.9 | 0.358 | 0.785 | 1.143 |

TABLE II. SATURATED AMMONIA: PRESSURE TABLE

| Pres. Lb. per Sq.In. | Temp. F. | Spec. Vol. Cu.Ft. per Lb. Liquid | Spec. Vol. Cu.Ft. per Lb. Vapor | Total Heat of Liquid | Latent Heat of Evap. | Total Heat of Vapor | Entropy Liquid | Entropy Evap. | Entropy Vapor |
|---|---|---|---|---|---|---|---|---|---|
| 10.0 | —41.35 | 0.02318 | 25.79 | —1.3 | 597.9 | 596.6 | —0.003 | 1.429 | 1.426 |
| 10.5 | —39.71 | 0.02323 | 24.64 | +0.4 | 596.8 | 597.2 | +0.001 | 1.421 | 1.422 |
| 11.0 | —38.13 | 0.02326 | 23.59 | 2.0 | 595.7 | 597.9 | 0.005 | 1.414 | 1.419 |
| 11.5 | —36.62 | 0.02329 | 22.64 | 3.5 | 494.7 | 598.2 | 0.009 | 1.406 | 1.415 |
| 12.0 | —35.16 | 0.02333 | 21.75 | 5.1 | 593.7 | 598.8 | 0.012 | 1.399 | 1.411 |
| 12.5 | —33.74 | 0.02336 | 20.94 | 6.6 | 592.8 | 599.4 | 0.016 | 1.392 | 1.408 |
| 13.0 | —32.37 | 0.02339 | 20.19 | 8.1 | 591.9 | 600.0 | 0.019 | 1.385 | 1.404 |
| 13.5 | —31.04 | 0.02342 | 19.49 | 9.5 | 590.9 | 600.4 | 0.023 | 1.379 | 1.402 |
| 14.0 | —29.76 | 0.02345 | 18.84 | 10.9 | 590.0 | 600.9 | 0.026 | 1.373 | 1.399 |
| 14.5 | —28.51 | 0.02348 | 18.23 | 12.3 | 589.1 | 601.4 | 0.029 | 1.367 | 1.396 |
| 15.0 | —27.29 | 0.02351 | 17.66 | 13.6 | 588.3 | 601.9 | 0.032 | 1.361 | 1.393 |
| 15.5 | —26.11 | 0.02354 | 17.12 | 14.8 | 587.6 | 602.4 | 0.035 | 1.356 | 1.391 |
| 16.0 | —24.96 | 0.02357 | 16.62 | 16.1 | 586.8 | 602.9 | 0.038 | 1.350 | 1.388 |
| 16.5 | —23.83 | 0.02359 | 16.15 | 17.3 | 586.0 | 603.3 | 0.040 | 1.345 | 1.385 |
| 17.0 | —22.73 | 0.02362 | 15.71 | 18.4 | 585.2 | 603.6 | 0.043 | 1.340 | 1.383 |
| 17.5 | —21.66 | 0.02365 | 15.29 | 19.6 | 584.4 | 604.0 | 0.046 | 1.335 | 1.381 |
| 18.0 | —20.61 | 0.02367 | 14.89 | 20.7 | 583.7 | 604.4 | 0.048 | 1.330 | 1.378 |
| 18.5 | —19.59 | 0.02370 | 14.52 | 21.8 | 583.0 | 604.8 | 0.051 | 1.325 | 1.376 |
| 19.0 | —18.59 | 0.02372 | 14.16 | 22.9 | 582.3 | 605.2 | 0.053 | 1.320 | 1.373 |
| 19.5 | —17.61 | 0.02375 | 13.82 | 24.0 | 581.6 | 605.6 | 0.056 | 1.316 | 1.372 |
| 20.0 | —16.65 | 0.02377 | 13.50 | 25.0 | 580.9 | 605.9 | 0.058 | 1.311 | 1.369 |
| 20.5 | —15.70 | 0.02379 | 13.19 | 26.0 | 580.2 | 606.2 | 0.060 | 1.307 | 1.367 |
| 21.0 | —14.78 | 0.02381 | 12.90 | 26.9 | 579.6 | 606.5 | 0.062 | 1.303 | 1.365 |
| 21.5 | 13.88 | 0.02383 | 12.62 | 27.9 | 578.9 | 606.8 | 0.065 | 1.299 | 1.364 |
| 22.0 | —12.98 | 0.02386 | 12.35 | 28.9 | 578.3 | 607.2 | 0.067 | 1.294 | 1.361 |
| 22.5 | —12.11 | 0.02388 | 12.10 | 29.8 | 577.7 | 607.5 | 0.069 | 1.291 | 1.360 |
| 23.0 | —11.25 | 0.02390 | 11.85 | 30.7 | 577.0 | 607.7 | 0.071 | 1.287 | 1.358 |
| 23.5 | —10.41 | 0.02392 | 11.62 | 31.7 | 576.4 | 608.1 | 0.073 | 1.283 | 1.356 |
| 24.0 | — 9.58 | 0.02394 | 11.39 | 32.6 | 575.8 | 608.4 | 0.075 | 1.280 | 1.355 |
| 24.5 | — 8.77 | 0.02397 | 11.17 | 33.4 | 575.2 | 608.6 | 0.077 | 1.276 | 1.353 |
| 25.0 | — 7.96 | 0.02399 | 10.96 | 34.3 | 574.6 | 608.9 | 0.079 | 1.272 | 1.351 |
| 25.5 | — 7.17 | 0.02401 | 10.76 | 35.1 | 574.0 | 609.1 | 0.081 | 1.269 | 1.350 |
| 26.0 | — 6.40 | 0.02403 | 10.56 | 36.0 | 573.5 | 609.5 | 0.082 | 1.265 | 1.347 |
| 26.5 | — 5.63 | 0.02405 | 10.37 | 36.8 | 572.9 | 609.7 | 0.084 | 1.262 | 1.346 |
| 27.0 | — 4.88 | 0.02406 | 10.19 | 37.6 | 572.3 | 609.9 | 0.086 | 1.259 | 1.345 |
| 27.5 | — 4.14 | 0.02409 | 10.02 | 38.4 | 571.7 | 610.1 | 0.088 | 1.255 | 1.343 |
| 28.0 | — 3.40 | 0.02411 | 9.85 | 39.2 | 571.2 | 610.4 | 0.089 | 1.252 | 1.341 |
| 28.5 | — 2.68 | 0.02412 | 9.69 | 40.0 | 570.7 | 610.7 | 0.091 | 1.249 | 1.340 |
| 29.0 | — 1.97 | 0.02414 | 9.53 | 40.7 | 570.2 | 610.9 | 0.092 | 1.246 | 1.338 |
| 29.5 | — 1.27 | 0.02416 | 9.38 | 41.5 | 569.6 | 611.1 | 0.094 | 1.243 | 1.337 |
| 30 | — 0.58 | 0.02418 | 9.235 | 42.3 | 569.1 | 611.4 | 0.096 | 1.240 | 1.336 |
| 31 | + 0.78 | 0.02421 | 8.955 | 43.8 | 568.1 | 611.9 | 0.099 | 1.234 | 1.333 |
| 32 | 2.11 | 0.02424 | 8.691 | 45.2 | 567.1 | 612.3 | 0.102 | 1.228 | 1.330 |
| 33 | 3.40 | 0.02428 | 8.446 | 46.6 | 566.1 | 612.7 | 0.105 | 1.223 | 1.328 |
| 34 | 4.66 | 0.02431 | 8.212 | 47.9 | 565.2 | 613.1 | 0.108 | 1.217 | 1.325 |
| 35 | 5.89 | 0.02435 | 7.990 | 49.3 | 564.2 | 613.5 | 0.111 | 1.212 | 1.323 |
| 36 | 7.09 | 0.02438 | 7.781 | 50.6 | 563.2 | 613.8 | 0.114 | 1.207 | 1.321 |
| 37 | 8.27 | 0.02441 | 7.584 | 51.9 | 562.4 | 614.3 | 0.117 | 1.202 | 1.319 |
| 38 | 9.42 | 0.02444 | 7.396 | 53.2 | 561.5 | 614.7 | 0.119 | 1.197 | 1.316 |
| 39 | 10.55 | 0.02448 | 7.217 | 54.4 | 560.6 | 615.0 | 0.122 | 1.192 | 1.314 |
| 40 | 11.66 | 0.02450 | 7.047 | 55.6 | 559.7 | 615.3 | 0.125 | 1.188 | 1.313 |
| 41 | 12.74 | 0.02453 | 6.886 | 56.7 | 558.9 | 615.6 | 0.127 | 1.183 | 1.310 |
| 42 | 13.80 | 0.02456 | 6.731 | 57.9 | 558.1 | 616.0 | 0.130 | 1.179 | 1.309 |
| 43 | 14.85 | 0.02460 | 6.584 | 59.0 | 557.2 | 616.2 | 0.132 | 1.174 | 1.306 |
| 44 | 15.88 | 0.02462 | 6.442 | 60.2 | 556.4 | 616.6 | 0.134 | 1.170 | 1.304 |
| 45 | 16.88 | 0.02465 | 6.306 | 61.3 | 555.6 | 616.9 | 0.137 | 1.166 | 1.303 |
| 46 | 17.87 | 0.02468 | 6.177 | 62.4 | 554.8 | 617.2 | 0.139 | 1.162 | 1.301 |
| 47 | 18.84 | 0.02471 | 6.053 | 63.4 | 554.0 | 617.4 | 0.141 | 1.158 | 1.299 |
| 48 | 19.80 | 0.02473 | 5.935 | 64.5 | 553.3 | 617.8 | 0.143 | 1.154 | 1.297 |
| 49 | 20.74 | 0.02475 | 5.820 | 65.5 | 552.5 | 618.0 | 0.145 | 1.150 | 1.295 |
| 50 | 21.67 | 0.02478 | 5.711 | 66.5 | 551.8 | 618.3 | 0.147 | 1.147 | 1.294 |
| 51 | 22.58 | 0.02481 | 5.605 | 67.5 | 551.0 | 618.5 | 0.150 | 1.143 | 1.293 |
| 52 | 23.48 | 0.02483 | 5.504 | 68.5 | 550.3 | 618.8 | 0.152 | 1.139 | 1.291 |
| 53 | 24.36 | 0.02486 | 5.406 | 69.5 | 549.6 | 619.1 | 0.154 | 1.136 | 1.290 |
| 54 | 25.23 | 0.02489 | 5.312 | 70.5 | 548.9 | 619.4 | 0.156 | 1.132 | 1.288 |
| 55 | 26.09 | 0.02491 | 5.220 | 71.4 | 548.1 | 619.5 | 0.157 | 1.129 | 1.286 |
| 56 | 26.94 | 0.02494 | 5.132 | 72.3 | 547.5 | 619.8 | 0.159 | 1.125 | 1.284 |
| 57 | 27.77 | 0.02496 | 5.047 | 73.3 | 546.8 | 620.1 | 0.161 | 1.122 | 1.283 |
| 58 | 28.59 | 0.02499 | 4.965 | 74.2 | 546.1 | 620.3 | 0.163 | 1.119 | 1.282 |
| 59 | 29.41 | 0.02501 | 4.885 | 75.0 | 545.4 | 620.4 | 0.165 | 1.115 | 1.280 |
| 60 | 30.21 | 0.02503 | 4.808 | 75.9 | 544.7 | 620.6 | 0.167 | 1.112 | 1.279 |
| 61 | 31.00 | 0.02505 | 4.733 | 76.8 | 544.1 | 620.9 | 0.169 | 1.109 | 1.278 |
| 62 | 31.78 | 0.02507 | 4.660 | 77.7 | 543.5 | 621.2 | 0.170 | 1.106 | 1.276 |
| 63 | 32.55 | 0.02510 | 4.590 | 78.5 | 542.8 | 621.3 | 0.172 | 1.103 | 1.275 |
| 64 | 33.32 | 0.02512 | 4.522 | 79.3 | 542.1 | 621.4 | 0.174 | 1.100 | 1.274 |
| 65 | 34.07 | 0.02514 | 4.456 | 80.2 | 541.5 | 621.7 | 0.175 | 1.097 | 1.272 |
| 66 | 34.81 | 0.02517 | 4.392 | 81.0 | 540.9 | 621.9 | 0.177 | 1.094 | 1.271 |
| 67 | 35.54 | 0.02520 | 4.330 | 81.8 | 540.3 | 622.1 | 0.179 | 1.091 | 1.270 |
| 68 | 36.27 | 0.02522 | 4.269 | 82.6 | 539.7 | 622.3 | 0.180 | 1.088 | 1.268 |
| 69 | 36.99 | 0.02524 | 4.210 | 83.4 | 539.0 | 622.4 | 0.182 | 1.085 | 1.267 |
| 70 | 37.70 | 0.02526 | 4.153 | 84.2 | 538.4 | 622.6 | 0.183 | 1.083 | 1.266 |
| 72 | 39.10 | 0.02530 | 4.043 | 85.8 | 537.2 | 623.0 | 0.187 | 1.077 | 1.264 |
| 74 | 40.46 | 0.02534 | 3.939 | 87.3 | 536.1 | 623.4 | 0.190 | 1.072 | 1.262 |
| 76 | 41.80 | 0.02538 | 3.840 | 88.8 | 534.9 | 623.7 | 0.193 | 1.067 | 1.260 |
| 78 | 43.11 | 0.02542 | 3.746 | 90.2 | 533.7 | 623.9 | 0.195 | 1.062 | 1.257 |
| 80 | 44.40 | 0.02546 | 3.657 | 91.6 | 532.6 | 624.2 | 0.198 | .057 | 1.255 |
| 82 | 45.66 | 0.02550 | 3.572 | 93.1 | 531.5 | 624.6 | 0.201 | 1.052 | 1.253 |
| 84 | 46.89 | 0.02555 | 3.490 | 94.5 | 530.4 | 624.9 | 0.204 | 1.047 | 1.251 |
| 86 | 48.11 | 0.02558 | 3.413 | 95.8 | 529.4 | 625.2 | 0.206 | 1.043 | 1.249 |
| 88 | 49.30 | 0.02562 | 3.339 | 97.1 | 528.3 | 625.4 | 0.209 | 1.038 | 1.247 |
| 90 | 50.47 | 0.02566 | 3.268 | 98.4 | 527.3 | 625.7 | 0.212 | 1.034 | 1.246 |
| 92 | 51.62 | 0.02570 | 3.200 | 99.7 | 526.2 | 625.9 | 0.214 | 1.029 | 1.243 |
| 94 | 52.76 | 0.02573 | 3.135 | 101.1 | 525.1 | 626.2 | 0.216 | 1.025 | 1.241 |
| 96 | 53.87 | 0.02577 | 3.072 | 102.3 | 524.1 | 626.4 | 0.219 | 1.021 | 1.240 |
| 98 | 54.97 | 0.02581 | 3.012 | 103.5 | 523.1 | 626.6 | 0.221 | 1.017 | 1.238 |

TABLE II. (Continued)

| Pres. Lb per Sq.In. | Temp. F. | Spec. Vol. Cu.Ft. per Lb. Liquid | Spec. Vol. Cu.Ft. per Lb. Vapor | Total Heat of Liquid | Latent Heat of Evap. | Total Heat of Vapor | Entropy Liquid | Entropy Evap | Entropy Vapor |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 56.05 | 0.02584 | 2.954 | 104.8 | 522.1 | 626.9 | 0.224 | 1.013 | 1.237 |
| 102 | 57.11 | 0.02587 | 2.899 | 105.9 | 521.1 | 627.0 | 0.226 | 1.009 | 1.235 |
| 104 | 58.16 | 0.02591 | 2.845 | 107.0 | 520.2 | 627.2 | 0.228 | 1.005 | 1.233 |
| 106 | 59.19 | 0.02595 | 2.794 | 108.2 | 519.2 | 627.4 | 0.230 | 1.001 | 1.231 |
| 108 | 60.21 | 0.02598 | 2.744 | 109.4 | 518.3 | 627.7 | 0.233 | 0.997 | 1.230 |
| 110 | 61.21 | 0.02602 | 2.696 | 110.5 | 517.3 | 627.8 | 0.235 | 0.993 | 1.228 |
| 112 | 62.20 | 0.02605 | 2.649 | 111.6 | 516.4 | 628.0 | 0.237 | 0.990 | 1.227 |
| 114 | 63.17 | 0.02609 | 2.604 | 112.8 | 515.4 | 628.2 | 0.239 | 0.986 | 1.225 |
| 116 | 64.13 | 0.02611 | 2.561 | 113.8 | 514.6 | 628.4 | 0.241 | 0.983 | 1.224 |
| 118 | 65.08 | 0.02614 | 2.519 | 114.9 | 513.6 | 628.5 | 0.243 | 0.970 | 1.222 |
| 120 | 66.02 | 0.02618 | 2.478 | 116.0 | 512.8 | 628.8 | 0.245 | 0.975 | 1.220 |
| 122 | 66.94 | 0.02621 | 2.439 | 117.0 | 511.9 | 628.9 | 0.247 | 0.972 | 1.219 |
| 124 | 67.86 | 0.02624 | 2.400 | 118.1 | 511.0 | 629.1 | 0.249 | 0.969 | 1.218 |
| 126 | 68.76 | 0.02627 | 2.363 | 119.1 | 510.1 | 629.2 | 0.251 | 0.966 | 1.217 |
| 128 | 69.65 | 0.02631 | 2.328 | 120.1 | 509.3 | 629.4 | 0.253 | 0.962 | 1.215 |
| 130 | 70.53 | 0.02634 | 2.293 | 121.1 | 508.4 | 629.5 | 0.255 | 0.959 | 1.214 |
| 132 | 71.40 | 0.02637 | 2.259 | 122.1 | 507.6 | 629.7 | 0.257 | 0.956 | 1.213 |
| 134 | 72.26 | 0.02640 | 2.226 | 123.1 | 506.7 | 629.8 | 0.258 | 0.953 | 1.211 |
| 136 | 73.11 | 0.02643 | 2.195 | 124.0 | 505.9 | 629.9 | 0.260 | 0.950 | 1.210 |
| 138 | 73.95 | 0.02646 | 2.164 | 125.0 | 505.1 | 630.1 | 0.262 | 0.947 | 1.209 |
| 140 | 74.79 | 0.02649 | 2.134 | 126.0 | 504.3 | 630.3 | 0.264 | 0.944 | 1.208 |
| 142 | 75.61 | 0.02652 | 2.104 | 126.9 | 503.5 | 630.4 | 0.265 | 0.941 | 1.206 |
| 144 | 76.42 | 0.02655 | 2.076 | 127.9 | 502.7 | 630.6 | 0.267 | 0.938 | 1.205 |
| 146 | 77.23 | 0.02658 | 2.048 | 128.8 | 501.9 | 630.7 | 0.269 | 0.935 | 1.204 |
| 148 | 78.02 | 0.02661 | 2.021 | 129.7 | 501.1 | 630.8 | 0.271 | 0.932 | 1.203 |
| 150 | 78.81 | 0.02663 | 1.995 | 130.6 | 500.3 | 630.9 | 0.272 | 0.929 | 1.201 |
| 152 | 79.59 | 0.02666 | 1.969 | 131.5 | 499.5 | 631.0 | 0.274 | 0.926 | 1.200 |
| 154 | 80.37 | 0.02669 | 1.944 | 132.4 | 498.7 | 631.1 | 0.275 | 0.924 | 1.199 |
| 156 | 81.13 | 0.02672 | 1.920 | 133.2 | 498.0 | 631.2 | 0.277 | 0.921 | 1.198 |
| 158 | 81.89 | 0.02675 | 1.896 | 134.2 | 497.1 | 631.3 | 0.279 | 0.918 | 1.197 |
| 160 | 82.64 | 0.02678 | 1.873 | 135.0 | 496.4 | 631.4 | 0.280 | 0.915 | 1.195 |
| 162 | 83.38 | 0.02681 | 1.851 | 135.9 | 495.6 | 631.5 | 0.282 | 0.913 | 1.195 |
| 164 | 84.12 | 0.02684 | 1.829 | 136.7 | 494.9 | 631.6 | 0.283 | 0.910 | 1.193 |
| 166 | 84.85 | 0.02687 | 1.807 | 137.5 | 494.2 | 631.7 | 0.285 | 0.908 | 1.193 |
| 168 | 85.57 | 0.02689 | 1.786 | 138.4 | 493.4 | 631.8 | 0.286 | 0.905 | 1.191 |
| 170 | 86.29 | 0.02692 | 1.766 | 139.2 | 492.7 | 631.9 | 0.288 | 0.903 | 1.191 |
| 172 | 87.00 | 0.02695 | 1.745 | 140.0 | 491.9 | 631.9 | 0.289 | 0.900 | 1.189 |
| 174 | 87.70 | 0.02698 | 1.726 | 140.8 | 491.2 | 632.0 | 0.291 | 0.897 | 1.188 |
| 176 | 88.40 | 0.02701 | 1.706 | 141.6 | 490.5 | 632.1 | 0.292 | 0.895 | 1.187 |
| 178 | 89.09 | 0.02703 | 1.687 | 142.4 | 489.7 | 632.1 | 0.294 | 0.893 | 1.187 |
| 180 | 89.78 | 0.02706 | 1.669 | 143.2 | 489.0 | 632.2 | 0.295 | 0.890 | 1.185 |
| 182 | 90.46 | 0.02709 | 1.651 | 144.0 | 488.3 | 632.3 | 0.297 | 0.888 | 1.185 |
| 184 | 91.13 | 0.02712 | 1.633 | 144.8 | 487.6 | 632.4 | 0.298 | 0.885 | 1.183 |
| 186 | 91.80 | 0.02714 | 1.616 | 145.6 | 486.9 | 632.5 | 0.299 | 0.883 | 1.182 |
| 188 | 92.47 | 0.02717 | 1.599 | 146.4 | 486.1 | 632.5 | 0.301 | 0.881 | 1.182 |
| 190 | 93.13 | 0.02720 | 1.582 | 147.1 | 485.5 | 632.6 | 0.302 | 0.878 | 1.180 |
| 192 | 93.78 | 0.02722 | 1.566 | 147.9 | 484.8 | 632.7 | 0.304 | 0.876 | 1.180 |
| 194 | 94.43 | 0.02725 | 1.550 | 148.7 | 484.1 | 632.8 | 0.305 | 0.874 | 1.179 |
| 196 | 95.07 | 0.02727 | 1.534 | 149.4 | 483.4 | 632.8 | 0.306 | 0.872 | 1.178 |
| 198 | 95.71 | 0.02730 | 1.518 | 150.2 | 482.7 | 632.9 | 0.308 | 0.869 | 1.177 |
| 200 | 96.34 | 0.02733 | 1.503 | 150.9 | 482.0 | 632.9 | 0.309 | 0.867 | 1.176 |
| 205 | 97.91 | 0.02739 | 1.467 | 152.7 | 480.3 | 633.0 | 0.312 | 0.862 | 1.174 |
| 210 | 99.43 | 0.02745 | 1.432 | 154.5 | 478.6 | 633.1 | 0.315 | 0.856 | 1.171 |
| 215 | 100.94 | 0.02752 | 1.399 | 156.3 | 477.0 | 633.3 | 0.318 | 0.851 | 1.169 |
| 220 | 102.42 | 0.02758 | 1.367 | 158.0 | 475.3 | 633.3 | 0.321 | 0.846 | 1.167 |
| 225 | 103.88 | 0.02764 | 1.337 | 159.8 | 473.7 | 633.5 | 0.325 | 0.841 | 1.166 |
| 230 | 105.31 | 0.02770 | 1.308 | 161.4 | 472.2 | 633.6 | 0.327 | 0.836 | 1.163 |
| 235 | 106.71 | 0.02776 | 1.280 | 163.1 | 470.5 | 633.6 | 0.330 | 0.831 | 1.161 |
| 240 | 108.10 | 0.02782 | 1.253 | 164.7 | 468.9 | 633.6 | 0.333 | 0.826 | 1.159 |
| 245 | 109.45 | 0.02788 | 1.227 | 166.3 | 467.4 | 633.7 | 0.336 | 0.821 | 1.157 |
| 250 | 110.80 | 0.02794 | 1.202 | 168.0 | 465.8 | 633.8 | 0.339 | 0.817 | 1.156 |
| 255 | 112.12 | 0.02800 | 1.179 | 169.5 | 464.3 | 633.8 | 0.341 | 0.812 | 1.153 |
| 260 | 113.42 | 0.02806 | 1.156 | 171.0 | 462.8 | 633.8 | 0.344 | 0.808 | 1.152 |
| 265 | 114.71 | 0.02312 | 1.134 | 172.7 | 461.2 | 633.9 | 0.347 | 0.803 | 1.150 |
| 270 | 115.97 | 0.02817 | 1.112 | 174.2 | 459.7 | 633.9 | 0.349 | 0.799 | 1.148 |
| 275 | 117.22 | 0.02823 | 1.092 | 175.7 | 458.2 | 633.9 | 0.352 | 0.794 | 1.146 |
| 280 | 118.45 | 0.02829 | 1.072 | 177.1 | 456.8 | 633.9 | 0.354 | 0.790 | 1.144 |
| 285 | 119.66 | 0.02835 | 1.053 | 178.6 | 455.3 | 633.9 | 0.357 | 0.786 | 1.143 |
| 290 | 120.86 | 0.02840 | 1.035 | 180.1 | 453.9 | 634.0 | 0.359 | 0.782 | 1.141 |
| 295 | 122.05 | 0.02846 | 1.016 | 181.5 | 452.4 | 633.9 | 0.361 | 0.778 | 1.139 |
| 300 | 123.21 | 0.02852 | 0.998 | 183.0 | 450.9 | 633.9 | 0.364 | 0.774 | 1.137 |

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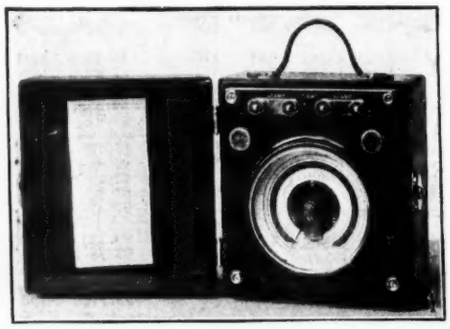
The exhaust valve of a Diesel engine usually opens about 40 deg. before outer dead center. It is necessary that the exhaust open before the end of the stroke to enable the burnt gases to escape quickly and without back pressure during the exhaust stroke. The admission valve opens before the end of the exhaust stroke. The inertia of the burnt gases passing out of the exhaust valve serves to completely empty the compression space, which is then filled by fresh air entering through the admission valve. The admission valve always closes after the piston has completed its suction stroke. The inertia of the fresh air entering through the air valve serves to compress the air charge slightly. If the admission valve is then held open a brief period, the entire cylinder will be filled with air above the pressure that would otherwise exist.

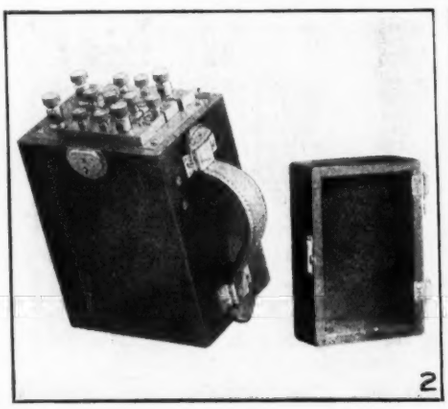
# Testing Alternating-Current Relays

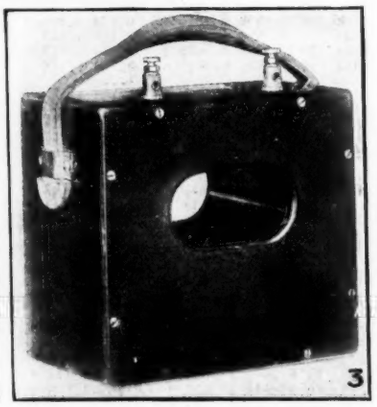
## Methods of Testing and Adjusting Both Current and Voltage Relays—Equipment for Use in Making Tests—Schemes for Obtaining Test Loads—How Adjustments are made—Tabulation of Test Data

By VICTOR H. TODD
Test Engineer, Westinghouse Electric and Manufacturing Company

FOR testing purposes relays may be divided into three classes—those requiring current alone for their operation, those requiring voltage alone, and those requiring both current and voltage. Since the majority of relays operate on current alone, this class will be considered first. When testing current relays, there are five main points to be considered: The source of power for testing; load and its regulation measuring instruments; trip circuit; measurement of the relay's time of operation. If possible, the preferred way to test a relay is to make a dead short-circuit on the protected apparatus and see if the relay operates and opens the breaker. However, this is seldom possible, but an occasional accidental "short" which is properly cleared, is the best assurance that the protective apparatus as a whole is functioning properly. Instead of waiting for the accidental short to occur, it is customary to subject the relays and auxiliary apparatus to periodic tests to determine if they are in condition to clear actual trouble. Thus in testing, the relays are disconnected from the circuit and current supplied from an independent source. The trip is also disconnected from the circuit breaker, and a signal lamp or cycle counter connected in to determine the time. Since the independent source of testing current need supply only the power required by the relay (100 watts at the most), it is customary to use the ordinary lighting circuit as the source. The power supply must have the same frequency as the normal frequency of the relay.







FIGS. 1 TO 3. PORTABLE AMMETER AND CURRENT TRANSFORMERS

The relay may be of the series type, in which case it is known as a primary relay. Or it may be wound to operate from the secondary of a series transformer and is then known as the secondary type. Standard practice is to use approximately 5 amperes for secondary-relay operation. Loading up a primary relay sometimes becomes a difficult matter, especially in the larger size, but loading a secondary relay is very simple on account of the small current required. A 5-ampere relay requires resistance, or reactance in series with it, if the current is to be taken from a 110-volt circuit. This may be a lamp bank, a resistance unit or a choke coil. Reactances are seldom used, as the wave form of their currents are liable to be peaked, and while present-day relays are but slightly affected by distorted wave forms, it is undesirable to introduce any possible source of error.

For heavy loads a water rheostat is often used. This consists merely of two metal plates placed in a pail or barrel of acidulated or salt water. The current strength is varied by varying either the distance between the plates or the density of the solution. The voltage required to force current through the relay windings is very low, amounting to less than 5 volts in many cases. Therefore, instead of using 5 amperes at 110 volts, we may transform from 110 to 5 volts. The figure 5 was assumed in the foregoing cases only to illustrate the necessity of secondary voltage. In actual practice the voltage is neither known nor desired to be known, as it is varied until it produces the proper current, which alone must be measured, regardless of whether the voltage is 1, 2, 8 or 10 volts. This is called a phantom load as it permits of a large testing current and still draws only a small current from the supply circuit.

For testing current relays, the standard instrument is an ammeter. This should be a high-class instrument, having reliable accuracy, rugged in construction, deadbeat; that is, when current is applied, it should not overswing the mark, but indicate quickly without oscillation or vibration. It should be correct on wide variations in frequency and have large, open divisions, making it easily read.

Induction-type meters are good all-around instruments, one type of which is shown in Fig. 1. If the two links span the two outside posts marked "10

amperes" in the figure, the pointer deflects to full scale on 10 amperes, but if the links span the two posts marked "5 amperes," then full-scale deflection is obtained on 5 amperes. When used with a current transformer having a variable ratio, great flexibility is obtained. A transformer of this type is shown in Fig. 2. This has primary values of 25, 50 and 100 amperes, which are changed by rearranging the plugs according to directions which are furnished with the transformer. For higher current the transformer in Fig. 3 is used. Two ranges may be supplied; 400 amperes and 1,600 amperes. The primary is formed merely by passing the wire or cable through the hole. By passing two turns through the hole, the ratio is changed from 400 to 5 to 200 to 5 or from 1,600 to 5 to 800 to 5, according to the transformer used. Four turns changes the ratios to 100 to 5 and 400 to 5 respectively. If the current is greater than 1,600 amperes, the 10-ampere range on the meter is used, making it possible to measure up to 3,200 amperes, using the same ratio or, rather, 3,200 to 10. There is a slight error when used in the latter manner.

When testing a shunt-trip relay, the contacts open the circuit when the relay resets and may burn them slightly, therefore, use a small lamp in circuit and, before the last time the relay closes, clean the contact thoroughly with a piece of fine emery cloth or paper. Never use red crocus paper as it often leaves a muddy coating, which prevents good electrical contact. It is good practice after cleaning the contacts, to draw a piece of ordinary paper or cloth between them in order to remove all traces of emery dust. After cleaning, try the relay just once to make sure that nothing was damaged in cleaning.

For ordinary relays, except those used for sectionalizing, a stop watch does very nicely for determining the time. First the load is adjusted and the relay is allowed

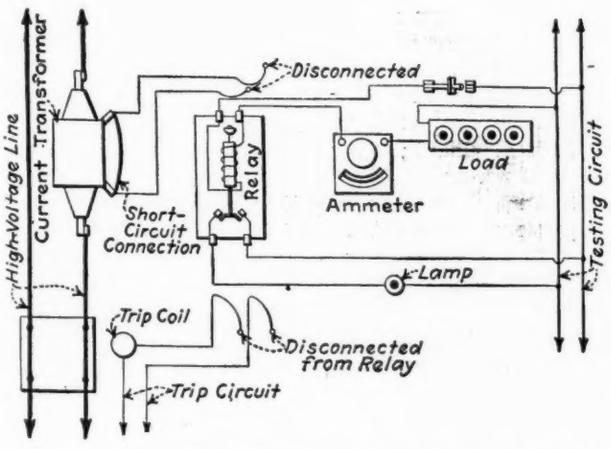



FIG. 4. TESTING CONNECTIONS FOR BELLOWS-TYPE RELAY

to fully reset, then the watch is started and the load switch closed at the same instant. The instant that the relay trips (lights the signal lamp), the watch is stopped and the time noted. For more accurate time, as is required for sectionalizing relays on a radial or ring system, it is necessary to use a cycle counter. This was described in Nov. 9, 1920, issue, and the diagrams of testing connections will be taken up next.

When all the apparatus, including load box, ammeter, trip lamp and various leads and tools, are ready, and before touching the relay, there are two things to be done—one of paramount importance and one a smaller detail. First: short-circuit the current transformer right at the secondary leads. A current transformer must never be open-circuited when there is load on the primary, as not only may it harm the transformer, but it may induce a voltage of several thousand volts, making it a source of great personal danger. No harm can come of short-circuiting a current or series transformer. Many modern installations have a

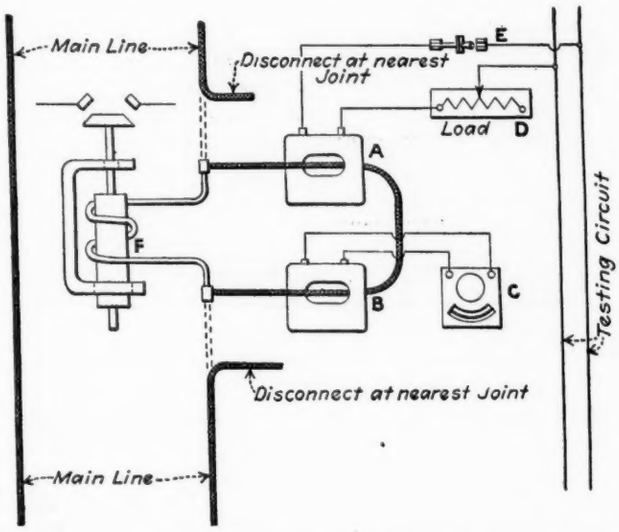



FIG. 5. CONNECTIONS FOR TESTING HEAVY-CURRENT RELAYS

permanently mounted switch which short-circuits the secondary, but in its absence a short lead with two heavy-spring testing clips should be used and fastened so that they cannot possibly drop off. The second point is to wipe off all the dust or dirt from the relay cover before removing it.

Assume, for the first example, that it is a 5-ampere bellows-type relay that is to be tested. It operates from a series transformer placed in the high-tension line. A separate source is available for testing and a lamp load is used. Fig. 4 shows the connections ready for testing. The transformer is short-circuited, the relay disconnected at both top and bottom, the load, ammeter, relay coil and switch are connected in series across the line, and the trip is connected in with a signal lamp.

Of course, if the circuit may be interrupted, it is not necessary to disconnect the trip; the breaker itself may be actually opened when the relay trips. This is really preferable, but often impossible to do. The switch is closed and the load adjusted until the meter shows the correct current, then the switch is opened and the relay fully reset. Quickly closing the switch, snap the stop watch to start, and the instant the lamp lights or the breaker trips, snap the watch to stop it. This gives the time of delay between overload and tripping. To obtain very accurate time, as is necessary with sectionalizing relays, a cycle counter is used as already referred to.

The problem of testing a heavy-current series relay is a more difficult one, as it is necessary to interrupt the circuit in most cases, unless the load can be built up on the lines. In this case, however, it is very difficult to get an accurate time as it is hard to apply a heavy load in a quick, accurate manner.

A good way to test series relays up to several hundred amperes, is to use a phantom load, obtained by using a

series transformer inverted. Fig. 5 shows the correct connections. The relay is disconnected from the main line. (This is not necessary if it is a low-tension circuit and if it has no current flowing.) A short section of heavy cable is run through two transformers, *A* and *B*, and connected to the relay coil *F*. Current is now passed through the secondary of transformer *A* with load *D* and switch *E* in series. This current induces a voltage in the loop of wire, and since its resistance is low, a heavy current flows in the relay

| | Time in Seconds to Trip | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Times Current Tap Setting 1.5 | 0.5 | 1.1 | 1.7 | 2.3 | 2.9 | 3.7 | 4.7 | 5.9 | 7.2 | 8.8 |
| 2 | 0.4 | 0.8 | 1.1 | 1.5 | 2.0 | 2.5 | 3.1 | 3.9 | 4.6 | 5.6 |
| 3 | 0.3 | 0.6 | 0.8 | 1.1 | 1.4 | 1.8 | 2.2 | 2.7 | 3.2 | 4.0 |
| 5 | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 | 1.7 | 2.0 | 2.5 | 3.0 |
| 10 | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | 1.7 | 2.0 | 2.4 |
| 20 | 0.2 | 0.4 | 0.5 | 0.7 | 0.8 | 1.0 | 1.2 | 1.5 | 1.8 | 2.2 |
| 30 | 0.2 | 0.3 | 0.5 | 0.6 | 0.8 | 0.9 | 1.1 | 1.4 | 1.7 | 2.0 |
| 50 | 0.2 | 0.3 | 0.4 | 0.6 | 0.7 | 0.8 | 1.0 | 1.3 | 1.6 | 1.9 |
| Lever Setting | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

FIG. 6. TABLE GIVING TIME TO TRIP FOR DIFFERENT LEVER SETTINGS AND CURRENT TAPS

circuit, which is measured by the transformer *B* and the meter *C*.

For instance, using a transformer 400 to 5 amperes, when meter *C* reads 5 amperes, it will be known that there is 400 amperes in the relay circuit. It may, however, take only about 6 amperes from the line to produce this current. Should one turn in the transformer *A* not give enough current the turns may be increased to two or three and the current from the load increased accordingly. A good combination for 400 amperes is to use a 1,600 to 5 transformer at *A* with four turns of heavy wire for the primary. The trip circuit may be connected with a lamp or cycle counter, as previously described.

There are so many different makes of relays and principles of operation that it is impossible to give explicit directions for the adjustment of each and every

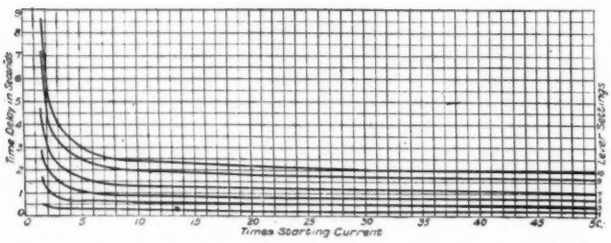



FIG. 7. CURVES OF RELAY FOR DIFFERENT LEVER SETTINGS AND CURRENT TAPS

one. This, however, is hardly necessary as each manufacturer gives directions for adjusting his particular relay and of course these should be followed.

In the plunger-type relays the tripping current is adjusted by varying the position of the core on the stem. This stem is generally threaded and the core or plunger screwed into position and locked with a setscrew or locknut, so that the vibration found in this type of relay cannot jar it loose. If there are springs which tend to offset the weight of the plunger, these may also be adjusted to change the tripping-current value. In the induction type the adjustment is generally made by pulling in or letting out some of the spiral spring which resists the turning effort of the disk. This is a delicate job and should be undertaken only by an experienced instrument man. Slight adjustments can sometimes be made by changing the position of the torque compensator with respect to the base.

The time of the bellows and oil-lagged relays is varied both by the distance of contact travel and the size of the opening in the needle valve. The contact disk is generally placed loosely between two nuts on the threaded shaft and may be raised or lowered, thereby making the plunger travel a longer or shorter distance and giving a longer or shorter time delay. The time of induction-type relays is varied by moving the permanent magnets in or out. Moving the magnets in toward the center of the disk gives a shorter time, and moving them out to within one-quarter inch of the edge gives a longer time. Great care must be taken that the disk does not touch the magnet as it turns and that there is no iron dust or filings on the magnets which may touch the disk. A feather or a piece of soft-iron wire is excellent in removing filings. Before leaving a relay, make sure that every screw and nut is tight; see that the contacts are clean; that there are no loose connections, burnt coils or insulation, dirt or dust; and that all moving parts move freely without sticking or rubbing. Also see that the leather on the bellows relays is soft and pliable, using, if necessary, a little neatsfoot oil to keep it soft. Make sure that all connections are returned exactly as found. If there are several connections to be removed and there is any possibility of getting them interchanged, make a sketch of the relay and terminals and number each terminal, 1, 2, 3, etc., on the sketch. Then, as the wires are removed, tie on each one a small tag marked according to the sketch, so that the leads will be correctly replaced. After all connections are completed, remove the short on the series transformer. Connect an ammeter in parallel with the current coil and see by its indication that current is flowing. The ammeter will divert part of the current from the relay. Connect a voltmeter across the trip-circuit terminals and see by its indication that the trip circuit is intact right up to the relay contacts.

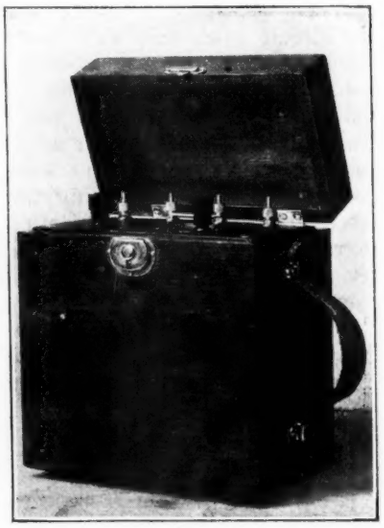


FIG. 8. PORTABLE VOLTAGE TRANSFORMER

The time results under various loads are easily plotted in curve form or tabulated, thus rendering a permanent record of the action of the relay under various conditions. These form a ready source of reference by which the time of the relay may be easily changed, as might be necessary due to a change in the distribution of the load or the addition of various equipment.

If the results are tabulated, they should be somewhat similar to the table shown in Fig. 6. The vertical

columns are the time results of the various lever settings, and the horizontal lines are the time for the various loads. In making the test, set the relay lever to No. 1 setting and adjust the load to 1.5 times the tap setting. Thus if the 5-ampere tap is used, the current must be 7.5 amperes. The column may be in actual current or in per cent load. Apply the load and note the time. In this case it is 0.5 sec., 30 cycles on a cycle counter on a 60-cycle circuit. Put this down at

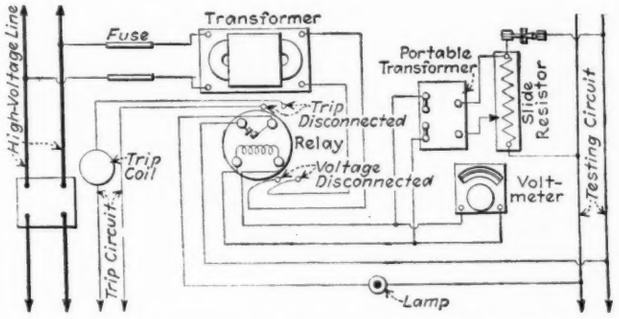



FIG. 9. CONNECTIONS FOR TESTING A VOLTAGE RELAY

the intersection of the No. 1 setting column and the 1.5 times current setting line. Try No. 2 setting, which gives a time of 1.1 sec. No. 3 setting requires 1.7 sec. and so on until all the settings have been tried, the load remaining at 1.5 times, or 7.5 amperes, during these ten tests. Now change the load to twice the current tap setting and take ten more readings with the different lever settings. This gives the figures for the second horizontal line. When getting heavier loads, say above 20 times or above 100 amperes, especially on the high lever settings, be sure the winding is thoroughly cooled off before making the next test, as sometimes a repeated heavy overload will change in time due to self-heating.

If preferred, a curve may be plotted on cross-section paper as shown in Fig. 7. The point of intersection between the current and lever setting is found and a dot marked. When a number of points have been located, a smooth curve is drawn through the points. A table like Fig. 6, is generally made first and then the curves are plotted. Intermediate time is easier to locate on a curve than on a table.

The apparatus generally used for testing voltage relays is a small portable transformer, a means of varying its voltage and a standard voltmeter. Of course, if a high enough voltage is available, it is unnecessary to use a small step-up transformer, but only means of cutting the voltage down to the proper amount. A small portable transformer is shown in Fig. 8, and while designed to step down from 400 or 200 to 100 volts, with accurately compensated ratio, it may also be used to step up from 100 to 200 or 400 volts with good results. The potential is varied by means of the adjustable slide resistor.

In preparing to make a test, the first thing to do is to disconnect the trip circuit and then open-circuit the potential transformer; never short-circuit it, as in the case of a series transformer, since this will blow a primary fuse or burn up the transformer. Connect the apparatus as in Fig. 9; inspect the relay mechanically, tightening all screws and nuts; clean the contacts and see that all moving parts are free to turn without rubbing or friction; see that the springs are intact, no burnt coils, and no filings clinging to the magnet. Then close the test switch and see that contacts close positively at the right voltage. If desirable, a table or curve may be made showing the relation between lever settings and closing or opening volts, or a curve may be made showing the length of time required to close the contacts.

Tests on a reverse-current relay generally comprise a complete test on the overload element and a thorough mechanical inspection to see that all parts are free to move without friction. In spite of all calculations of overload currents, distorted phase angles and other effects, there is only one sure way of determining if a certain installation of relays will protect, and that is by actually overloading or short-circuiting the lines, or producing the disturbance which it is desired to have cleared in case of its accidental occurrence. These are really installation tests, and once made need not be repeated, unless conditions occur which necessitate a revision of lines or apparatus. If it be known that the relays and connections give protection (from actual test), then it becomes only necessary to know that the instruments are mechanically intact, and this is determined by periodic inspection.

While directions have been given in this and preceding articles for the selection, installation and care of various relays, it must be understood that what gives satisfaction in one case may fail in another. Consequently, for any given installation it is necessary to study the system, the location of apparatus, their behavior under varying conditions and finally devise a system of protection that will cover the great majority of points, for it is frankly acknowledged that every point cannot be covered by any relay or combination in every case.

## Noncondensable Gases in Ammonia Absorption Refrigeration Machines*

In the experiments conducted at the Bureau of Standards the conditions existing during the operation of an ammonia absorption refrigeration machine were duplicated. It was found that the presence of the noncondensable gases that cause so much trouble in the operation of these plants is due to either or both of these causes; (1) Leaks of air into the system, and (2) the corrosive action of the aqua ammonia on the metal of the plant.

If the "foul" gas is mainly nitrogen, the gas is derived from air that is leaking into the system. The oxygen originally present in the air is quickly used up when the plant is operating and so will be present in only a very small percentage of its original amount. If the foul gas is hydrogen, the cause is corrosion by the ammonia liquor. Pure aqua ammonia will not cause gas formation; but if salts of such weak acids as acetic or carbonic acid are present in the "aqua," the corrosive action will continue during the life of the charge. If the gas contains both nitrogen and hydrogen, both causes are present.

The corrosive action of impure aqua may be completely stopped by the addition of either sodium or potassium dichromate to the aqua in the plant. The dichromate is conveniently added in the form of a concentrated solution, and gas formation will be stopped if the salt is added to the extent of 0.2 per cent of the weight of the aqua present.

*Abstract of Technologic Paper of the Bureau of Standards No. 180, by E. C. McKelvy and Aaron Isaacs.

# Timing Diesel Engine Valves

*The fuel or spray valve in the Diesel is the only valve requiring close adjustment. To secure smooth operation, the engineer should check these valves at intervals. Methods of finding dead centers and timing valves are explained.*

IN THE operation of a Diesel-engine station one of the most important duties the engineer is called upon to perform is that of adjusting and timing the various engine valves. With older machines where there exists a considerable amount of play or backlash in the camshaft gears, as well as a decided amount of cam wear, the exhaust and admission valves are often out of time and require correction. This adjustment can be secured by giving more or less clearance or by the use of offset keys in the cams. With the more modern Diesels it is practically impossible for any valve, other than the fuel-injection or spray valve, to become seriously out of time.

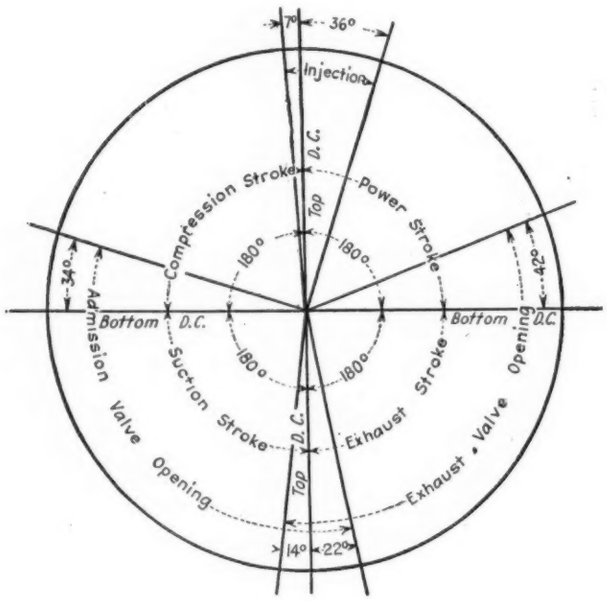



FIG. 1. TYPICAL DIESEL VALVE TIMING

A few degrees variation in the opening or closing point of the admission or exhaust valves has but little effect on the engine's behavior. In fact, the exhaust-pipe length and resistance, as well as the condition of the intake manifold, have more effect on the engine than has any minor mistiming of the exhaust or admission valves.

On the other hand, the fuel or spray valve should be reset each time the needle valve is reground. With many engines the operator times the point of opening of the spray valve by adjusting the clearance between the rocker-arm roller and its cam. If there is no wear either in the rocker-arm bearing or in the cam nose, the valve should open correctly provided the clearance is maintained at the same value as when the engine was first installed. Unfortunately, some slight wear is unavoidable and it is very difficult for the average operator to secure the proper clearance unless he knows how to use a feeler or clearance gage.

Engines of the several manufacturers vary in respect to valve timing; in fact, engines of the same make do not always have the same identical timing. An operator, on taking charge of a plant, should at once secure these data; if necessary, the manufacturer should be appealed to. The values given in Fig. 1 cover a Snow horizontal Diesel and are given here to acquaint the operator with typical values. In this diagram the entire circle represents 720 deg., or two revolutions of the crankshaft. Each quarter circle is, then, the space passed over by the crank while the piston makes one stroke; in this way the circle represents one complete cycle of a four-stroke-cycle engine.

The fuel injection valve is shown as opening 7 deg. before the piston has reached dead center. It must not be assumed that the oil actually is ignited 7 deg. before dead center. While the needle valve opens at this point, the resistance of the atomizer is such that the flow of oil does not start instantaneously, as there is a slight drag or retardation. Furthermore, after the oil injection has started it must be ignited. This, while taking only a fractional part of a second, does not occur until the piston reaches the end of its stroke. From the point at which the needle valve starts to open until the piston reaches dead center, not over $\frac{1}{100}$ of a second has elapsed. The fuel valve remains open until the crank has covered 36 deg. from top center. During this interval of valve opening the oil charge is passing into the cylinder. If the load on the engine is small, after the oil charge enters the cylinder, injection air continues to blow through the valve until it is closed. For this reason on low loads it is advisable to employ low air pressures to avoid loss of air as well as to avoid misfiring caused by excessive chilling from the air blast.

It is apparent that, beyond a slight variation in the amount of injection air, a decided difference in the time of closure of the fuel valve can be had without effect on the engine. Of course a decided shortening of the injection period might not provide sufficient time for the passage of the fuel charge under normal injection air pressures.

### Fuel Valve Must Open at the Proper Time

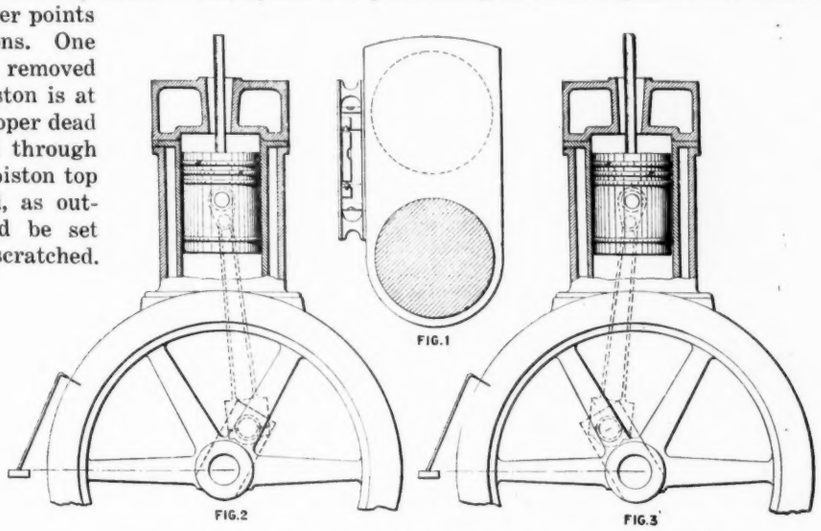
On the other hand, it is essential that the opening of the fuel valve should occur at the proper time. If too "early," part of the fuel will enter the cylinder and ignite before top dead center. The combustion of the oil will greatly increase the compression pressure. The engine will pound sharply, and if the opening is excessively early the power of the engine will drop.

It can rightly be concluded that the timing of the opening of the fuel valve is of importance and should be kept at the value recommended by the manufacturer. As already stated, some engineers set the valve by measuring the clearance between rocker roller and cam. The proper method is to set the valve opening by measurement of the crank angle. The indicator should be used to check the timing so secured. At stated intervals a diagram, preferably a right-angle one, should be taken from each cylinder.

Before proceeding to set any of the fuel valves, it is necessary to secure or make up a trammel rod and to set a base mark on the engine. Some engines are fitted with a mark on the frame from which distances can be measured on the flywheel. In case a mark must be pro-

vided, a small square of steel is best set into the engine foundation directly in front of the flywheel. Such an arrangement is shown in Fig. 2. A small center-punch mark placed on the upper surface will provide a point from which to use the trammel. The trammel can easily be made up of tool steel or of drill rod with both ends sharpened; the upper end should be bent at right angles to the rod, as shown. In many engines the dead-center crank positions are already marked on the flywheel; in this event the engine must be set on dead center and the trammel made of proper length to cut the dead-center mark. In this discussion it is assumed that no crank positions are marked and the engineer starts with his trammel of a proper length.

The next step is to determine the dead-center positions of the crank, especially the top or inner dead center. If the crank throws are machined square with the crank, it is possible to set the crank at D.C. by placing a spirit level against the crank throw and turning the engine until the level bubble registers horizontal. Many engines have built-up shafts without machined crank throws. These of course cannot be set with the level. It is never advisable to use this method, and it is here mentioned only to show what to avoid. The proper and only accurate method of determining the dead-center points is by measurement of the piston positions. One of the valves in the cylinder should be removed and the engine turned over until the piston is at a distance of six inches or so from the upper dead center. A steel scale may be inserted through the valve cavity and the distance from piston top to the edge of the valve opening noted, as outlined in Fig. 2. The trammel should be set against the flywheel and a light mark scratched. The engine is then turned until the piston passes upper dead center and retreats toward the position previously measured by the scale. The barring over of the flywheel should be slower as the point is approached. A second trammel mark is then made on the wheel, as in Fig. 3. By dividing the arc between the two trammel marks, the dead-center position is obtained. When the engine is turned so that the trammel just touches this latter mark, the crank of this cylinder is on dead center.




FIGS. 2 AND 3. METHODS OF LOCATING DEAD CENTERS

If the engine is a four-cylinder unit, the cranks will all lie in the same plane. It is here only necessary to determine the two opposite dead-center positions. Before definitely marking these dead-center points, they should be rechecked to avoid error. The points should then be marked by a letter set, for example: T 1-4, meaning top dead center of No. 1 and No. 4 cylinders.

Having the several dead-center positions marked on the flywheel, it is next necessary to set off on the rim the opening and closing points for the fuel valve. Usually, the valve timing is given in degrees of the crank circle and it becomes necessary to resolve these into inches on the flywheel. This is very easy; for example, with a 9-ft. wheel and a fuel valve opening at 7 deg. ahead of dead center, the length to be set off on the flywheel measuring ahead of the dead-center mark would be

$$\frac{7}{360} \times 9 \times 12 \times 3.14 = 6.6 \text{ inches.}$$

The point of fuel-valve opening and closure being marked on the flywheel, the next step is to remove the indicator plug in the cylinder head. The air injection valve is then cracked a slight amount to give about 250 lb. air pressure in the fuel valve. The engineer should then instruct his helper to bar the engine over in the running direction until the trammel just strikes the fuel-valve opening mark. This is, then, the point in the engine stroke where the fuel valve should open. If the timing is out, the engineer now moves the fuel-valve adjusting nut until he can, when placing his ear at the indicator opening, just barely hear the air blowing through the fuel valve. The air should be only faintly audible. It is best to turn the adjusting device until the air blows quite smartly and then turn it back until the air flow practically ceases. This times the point of opening. With this determined, the engine should be barred over until the valve closes. This should check with the mark already made on the flywheel, but if a difference of an inch or so appears it is of no serious concern.

To check the valve opening, the engine should be turned back and then barred over again, and as the opening point is reached the air should start blowing. In setting valves, the engine should always be turned ahead, and if a point being checked is passed, the wheel should be turned back again a matter of five or six inches past the mark to compensate for any backlash that might exist. This is of especial importance in old engines with much gear wear. During this process the admission or exhaust valve should be blocked open to allow the escape of the air displaced by the piston.

The same process is carried out for the several cylinders. If any of the cam noses are worn, the timing of the opening may allow excessive clearance between the roller and cam. This will cause a decided pound as the nose strikes the roller. Furthermore, if the wear of the nose is excessive the closing of the valve will come very late if the opening is set correctly. In such a case a new cam nose becomes imperative. In most engines the nose can be moved ahead to compensate partly for the wear. As has been stated, an inch or so discrepancy in the closing point is of little moment.

It is seldom that any adjustment need be made in the timing of the admission and exhaust valves. The easiest method of securing correct timing is by measuring the clearance between cam and roller. If it is desired to check these valves, the opening and closing points can

be marked in the flywheel and the engine barred over. To determine the point when the valve just starts to open, a small wrench placed on the valve end will show when the valve leaves its seat, since it will turn easily as soon as the contact pressure is relieved.

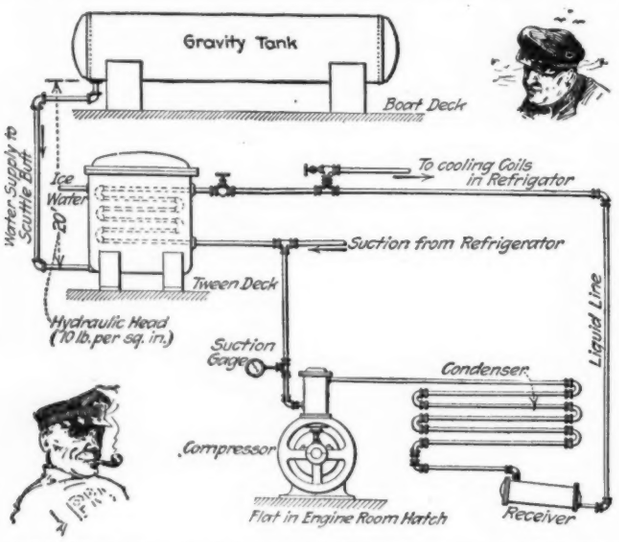
## Why the Steward Went Over the Side*

BY C. J. JEFFERSON

You may have noticed that there is no love lost between the engineers' and the stewards' departments on shipboard. We asked our friend, the Marine Engineer, the reason for this, and he explained it as follows:

"Marine engineers and ship stewards ceased to be professional friends upon the advent of refrigerating machines on shipboard.

"You see, the engineers who enter the refrigerators at night to read temperatures are apt to help themselves to lunches, while the stewards' force are so lacking in red corpuscles that they keep the refrigerator room




THE STEWARD, THE FIRST ASSISTANT AND THE SYSTEM

open unduly long while removing their stores, being generally very loath to work in freezing temperatures with closed doors.

"This feeling became greatly exaggerated on one of our cargo carriers during the war, and as the Old Man attached more importance to the lunches than to the efficiency of the engine room, the steward was given jurisdiction over the expansion valves.

"Now, the Steward didn't know a great deal about machinery, so he purchased a treatise on anhydrous ammonia, wherein he learned that the lower the pressure of the gas the lower the temperature produced. He also learned that the less the opening of a valve the less gas would go through, and concluded that the less gas in a given space the lower would be the pressure.

"The Engineer was a careful chap and jealous of the efficiency record of his department, so he had persuaded the port force to fit up the vessel with a fresh-water supply system, comprising a 500-gal. tank up on the boat deck, which was filled once a day and supplied all the water for drinking, culinary and sanitary purposes by gravity.

"Among other outlets there was one to the scuttle butt, which was located on the 'tween deck about twenty feet below the gravity tank and which, therefore, had a water pressure of about ten pounds to the square inch, due to the hydraulic head.

"For two days after the Steward came into power the expansion valves all went well, then trouble began to brew. The compressor knocked badly, the water supply from the scuttle butt became warm, the freezing coils in the refrigerating room lost their healthy frost and everything was generally upset. Then the Steward called for help, and control of the expansion valves was passed on to the Chief. He chuckled at first, then stopped chuckling, scratched his head, and began to search for new adjectives to describe the Steward, who had messed up his refrigerating plant. He had trouble in plenty and couldn't lay his finger on the source. He carried his ammonia at the pressure experience had taught him would produce the best results, but they were not forthcoming. The ammonia would not behave as ammonia ought to. Finally he drew off a test sample and it showed about 10 per cent moisture. He had found the trouble, but how did the moisture get in the system? He had double-pipe condensers but had pumped no vacuum on them nor had he pumped a vacuum on any part of the system, so it could not come from his water jackets. He went over the system again, took samples of water from the condenser and jacket and they showed no trace of ammonia, but when he sampled the water from the scuttle butt the phenolphthalein showed a bright red.

"Here was the source of the trouble. The coil in the scuttle butt was split, the water pressure inside it was 10 lb. to the square inch, and the Steward had operated with a 5-lb. pressure at the expansion valve. He went over the side the next day, just before the ship sailed."

As the M. E. stopped talking and puffed ruminatively on his pipe, we ventured to ask;

"Yes, but why did he—go over?"

"Why, you see, the First Assistant spent about fourteen hours recharging the plant, working on an engine hatchway flat where there was plenty of heat and mighty little ventilation, and when the Steward objected to his helping himself to coffee from the galley urn, there was an argument. The First Assistant weighed 190 pounds and was in good trim, while the Steward weighed only 140 and was flabby at that."

With which cryptic remark the Marine Engineer lurched silently forth into the darksome night.

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If the high-pressure suction valve leaks, the high-pressure gage will show a pressure drop while the intermediate discharge on the high-pressure intercooler pressure will show high. If the intermediate discharge valve leaks, the low-pressure intercooler pressure will rise while the high-pressure intercooler pressure will drop. If the low-pressure suction valve leaks, all the gages will drop, as will also happen if the low-pressure discharge valve leaks. In all cases of leaks through compressor valves the valve cages usually become quite hot.

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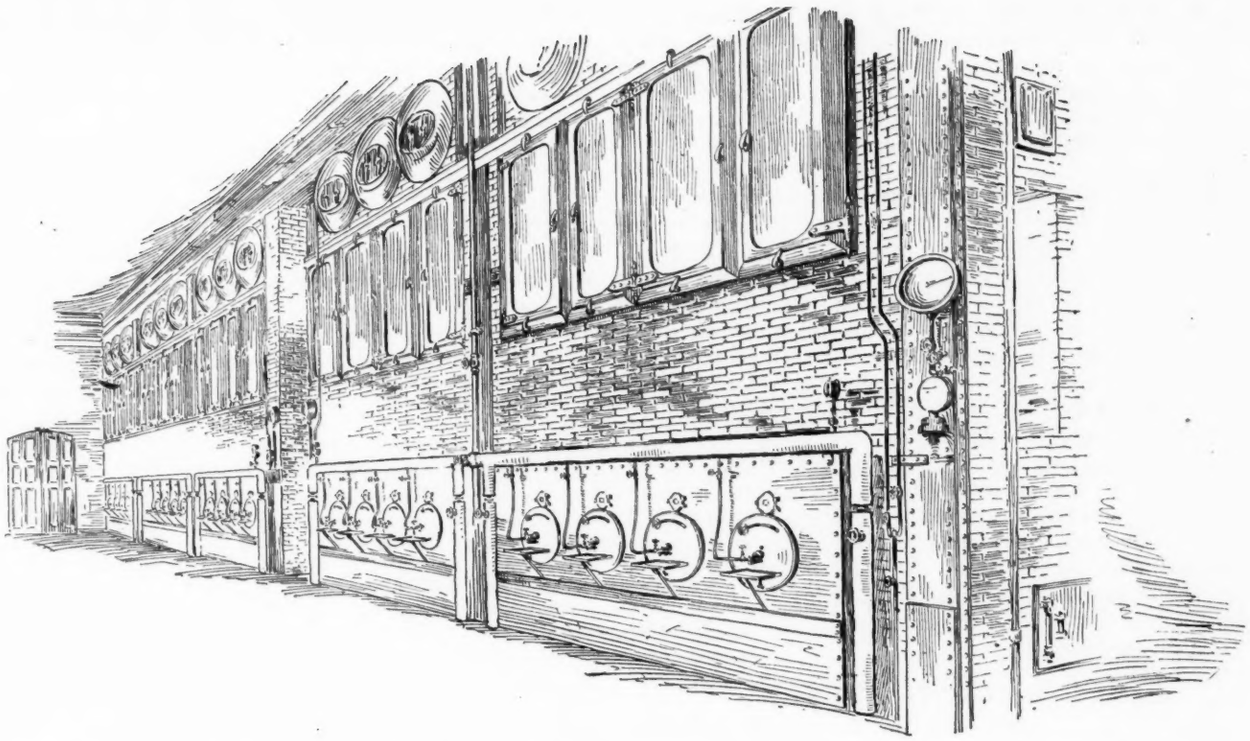
*For the benefit of non-seagoing *Power* readers the following glossary of terms used by the marine engineer is furnished.
Over the side: Equivalent to "out the gate"; euphemistic for "fired", "discharged."
Old Man: Captain, skipper.
Scuttle butt: Water cask; not to be confounded with its distant relative, the coal scuttle.
'Tween deck: There is some doubt about the meaning and origin of this phrase, but the consensus of opinion is that it denotes the deck between the one above and the one below



# Efficient Handling of Fuel Oil—II*

BY ALLEN F. BREWER

WHEN properly tended the flame in an oil-burning boiler furnace should appear steady in flow, not surging or in gusts. It should fill the entire furnace space. It should be a bluish white at the burner tip, changing about eight inches therefrom to a violet, then shading to a clear cherry red, and finally to a clear soft orange color as it extends into the furnace. The back wall of the furnace should be distinctly visible, and the gases of combustion should be practically colorless.

The extent to which a furnace roars is of considerable guidance as to the manner in which combustion is going on. Excess roaring means poor combustion and too much excess cold air. Roaring in a steam- or air-atomizing burner may also be caused by too much steam or air passing through the burner. Blast or blowpipe action should never be allowed to continue in any burner. Therefore aim to cut down on the roaring and increase the efficiency of combustion by cutting down the excess air and increasing its temperature.

### DEVELOPMENT OF SMOKE

The amount of smoke developed, together with the appearance of the flame at the time, is an excellent guide as to the efficiency of operation. The most perfect combustion is obtained when a slight haze or "feather of smoke" is just barely visible at the stack and the gases of combustion are colorless, the flame appearing as already described. Excess blackish smoke and dark yellow-red flame may be due to insufficient air, excess oil or incomplete atomization of the oil at the burner. Incomplete combustion, extra-heavy deposits of soot on the tubes and vibration will result if this is allowed to continue.

No smoke or heavy light smoke and white flame generally indicate too much excess air and result in a lowering of the evaporative efficiency, but are, of course, no guide as to the extent. A normally appearing flame and smoke, but with the presence of blackish streaks in the latter, is an indication of one or more dirty burners.

### AIR SUPPLY FOR COMBUSTION

Regulation of the air supply to conform to the load is essential if proper combustion is to be maintained. With flue-gas analysis at hand this is a simple matter. Without such equipment, however, the only guides are the appearance of flame and smoke. In that case regulation is best carried out by closing the dampers until a light excess gray smoke is visible, then opening the dampers slightly until the "feather of smoke" is produced.

The amount of air required for proper combustion—that is, theoretical plus excess—is about eighteen pounds per pound of oil burned. A convenient formula for calculating this, when the percentage of carbon and hydrogen in the fuel is known, is

$$\textit{Pounds of air (theoretical)} = 11.6 \times \textit{per cent carbon} + 34.8 \times \textit{per cent hydrogen}$$

To this theoretical weight of air add approximately 20 per cent as a sufficient excess, under normal operation.

Water or wet steam in the oil will cause sputtering of the flame and even at times extinguish it.

A dirty or partly clogged burner will cause a surging flame and give rise to imperfect atomization.

*The first article appeared Jan. 11, 1921.

It should be borne in mind that no matter how favorable the indications of flame, smoke and sound may point to proper combustion, they are far from being iron-bound. There is but one means to determine this to a practical certainty, and that is by an analysis of the flue gases. It is not proposed to describe this process or the apparatus involved. If the latter is a part of the equipment the fireman should aim to learn its operating thoroughly. Complete instructions are issued for the asking by the manufacturers. Flue-gas analysis is the only means to determine the exact regulation of the damper to conform to varying loads.

For the most efficient operation oil must be clean and hot, it must be fed to the burner at a steady pressure, and it must be completely burned before coming in contact with the heating surfaces whose cooling effect would tend to quench the fire.

Watch your furnace and flames frequently. Watch the smoke at the stack frequently. Keep the fireroom clear of spilled oil or leaks. Remember that an oil fire can be made to respond to an increase in load far quicker than a coal fire, therefore never force the former as much as seems possible, owing to the danger of burning out tubes and plates and risking your life from an explosion.

### Dont's for the Fireman

Don't stand directly in front of burner entrance when lighting off.

Don't hunt for leaks with a naked light.

Don't use a lighting-off torch less than four feet long.

Don't light off a burner from a seemingly hot brick wall; the danger of flareback is too great in case immediate ignition does not occur. If there is more than one burner in the furnace, however, a dead burner can be ignited from an adjacent lighted burner.

Don't allow unignited oil to spray into a furnace at any time from a burner or to drop from any part of the burner into the furnace. Such oil will collect on the furnace floor, give off vapor to mix with the air, and result in the accumulation of combustible gases, which may cause an explosion on the next lighting off if the furnace is not thoroughly ventilated.

Don't allow heating of fuel oil above its flash point in any part of the system except the burner. Excessive preheating will cause carbonization at the burner tip and unsteady burning, and there is ever a possibility of an explosion should small leaks be present in the line. Overheating the oil will cause a decrease in burner capacity in proportion to the temperature. Proper temperatures in general are 110 to 125 deg. F. for air or steam burners and in the neighborhood of 150 deg. F. for a mechanical burner. The temperature will of course depend entirely on the grade and gravity of the oil. Experience is the only final guide in heating to such a temperature as will give most complete vaporization. On the other hand, too low a temperature will cause flaming in the uptakes and injure the brickwork.

Don't ever figure that because you may have maintained the required steam pressure without a smoky stack you have operated most efficiently. Remember, the most economical results are gained by attaining complete combustion with the least possible excess air. On cloudy days the "feather of smoke" may become invisible and you may turn to a clear stack unknowingly, using far too much excess air and thereby carrying thousands of heat units up the stack. Your only precaution must be to carefully watch the flame as well as the stack. Remember, the more heat carried out of the furnace and up the stack the more fuel must be burned if an efficient rate of water evaporation is to be maintained.

Don't try to break $CO_2$ records or run too close to the maximum percentage of $CO_2$ possible (about 15 per cent). It is far too easy in such cases to use less air than required for proper combustion; CO will be produced, and the steam generation per pound of oil fired will drop to a marked extent. Between 12 and 13 per cent is a good average.

Don't use more steam than actually needed to give a soft, clear flame for a steam-atomizing burner; always regulate the steam at the steam valve to the burner. Excess steam will result in waste of this excess and the use of additional heat units in raising the temperature of this steam to that of the gases of combustion. Also, there will be a tendency to intense heat localization on the heating surfaces and on the brickwork, ultimately causing damage. An indication of excess atomizing steam is an intense white flame. To adjust steam for any oil flow, cut down on the former until drops of oil fall and burn on the furnace floor, then gradually open the steam valve until this action is corrected.

Don't neglect to use superheated steam whenever possible as an oil-atomizing agent; the higher the temperature of this steam the more complete will be the ultimate atomization of the oil.

Don't allow overload to occur due to scaled or sooted tubes, choked baffles, fallen brickwork or cold feed water. Excessive heat losses will always result if you do.

Don't let the oil pressure exceed that of the atomizing agent. The general practice is an excess of five pounds pressure of the atomizing agent over the oil pressure, in order to guard against the oil striking the back wall of the combustion chamber before combustion has been completed.

Don't wipe burners when cleaning with waste or cloth liable to shed lint, as shreds may catch on certain of the rough parts of the burner and cause clogging later if not completely removed.

## Equipment Valuation

A well-known consulting engineer of upper New York State, submits the following estimate of replacement values on power-plant equipment under present market conditions for machinery and labor. Plants are assumed as of from 500 to 1,000 kw. capacity, all units in place ready for service.

| | Per Hp. |
|---|---|
| Boilers (h.r.t. and water-tube) | $44 |
| Piping (for boilers, exclusive of feed piping) | 6 |
| Piping (exhaust to atmosphere) | 3 |
| Piping (boilers to engine) | 6 |
| Piping (feed-pump) | 2 |
| Engine—generator units | 53 |
| Turbine—generator units | 47 |
| Condensers | 8 |
| Coiler-feed pumps, each, $400. | |

Total for equipment listed, including necessary auxiliaries, such as feed-water heaters, oil separators, etc., from $210 to $240 per hp.

In view of the present unsettled condition on labor and materials it would be interesting to know how these figures compare with those obtainable in other localities.

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The first step the oil-engine operator should take in his effort to become an engineer is to subscribe to a magazine covering power machinery.

# Boiler Explosion at Creamery Kills Five

By J. P. MORRISON

THE high price, in connection with the difficulty and delay experienced in obtaining new boilers, has caused many plant owners to seek the used-boiler market when in recent need of additional equipment of that kind. In fact, the second-hand boiler, which a few years ago could find no takers, has been given a new lease on life as a "used boiler" and has had a ready market, principally in states where there is no law or regulations governing steam-boiler construction or in those states where the law or its enforcement is lax. Experienced operators and those possessing good engineering organizations, when in the second-hand market, have insisted that the boiler in which they have become interested be subjected to a rigid inspection before closing the transaction. In fact, many of the dealers in such equipment, who are confident of their goods, have suggested such a plan to prospective purchasers, but it is not unusual to encounter the customer who depends on his own engineering experience or on the veracity of the dealer to guide him in making the purchase. Seldom in such cases is any thought given to the fact that a boiler may be giving satisfactory service under certain conditions, but cannot be depended upon if relocated where the operating conditions are entirely different.

*Internally fired, used boiler originally designed for heating purposes was purchased by a creamery and operated with the slight protection afforded by a safety valve only ¾ in. in diameter and set to blow at 80 lb. pressure. The rear tube sheet was flanged outwardly to receive the internal flue, so that both heads of the rivets were exposed to the hot furnace gases and the construction generally warranted nothing more than low-pressure service. The explosion emphasizes the need for more rigid inspection of the second-hand boiler.*

Fig. 1 illustrates part of the damage done to the building of the Stoughton Marketing Co., of Stoughton, Wis., by the collapse of the furnace flue of an internally fired boiler, which failed on Nov. 24, 1920. Fig. 2 is a view of the combustion-chamber end of the boiler while resting in the alley where it lit, after passing through the air at a distance of about five feet above the ground for 150 ft. or more.

By the explosion four men and one woman were killed and two women were injured, one of the latter not being expected to recover. One man was standing at the side of the boiler, and was blown through the hole it made in the side of the building and into the coal bin, but was uninjured. The property damage is reported to amount to about $2,000 and consisted principally of injury to the dairy plant in which the boiler was operated and to the side wall of a building the boiler encountered in its flight.

The boiler is said to have been manufactured in 1904 by a Janesville, Wis., firm and designed for heating service. It was purchased by the Marketing company and installed in the Stoughton plant in September, 1920, and since that time had been in operation with its safety valve, which was but ¾ in. in diameter, set to operate at 80 lb. pressure.

Immediately preceding the accident the pressure gage indicated 40 lb., and there appears to have been an ample supply of water, judging from the statements made and by the fact that the rear ends of the tubes gave no indication of overheating, as well as the distance the boiler was projected.

Data secured on the boiler show that it was 54 in. in diameter and approximately five feet long. It contained twenty-six 3-in. fire tubes in addition to the 28-in. internal furnace flue. The longitudinal seam was of the double-riveted lap-joint type, and while not of the highest possible efficiency for that type of joint, it possessed ample strength for heating purposes. The shell plate

FIG. 1. SHOWING THE DAMAGE DONE TO THE CREAMERY BUILDING

FIG. 2. REAR HALF OF BOILER PROJECTED TO A POINT 150 FT. DISTANT

FIG. 3. CLOSE-UP OF REAR HEAD SHOWING COLLAPSED FLUE AND THE DOUBLE EXPOSURE OF THE RIVETS TO THE HOT GASES

was of ½-in. steel, as was also the furnace flue, and each was formed of one section. The heads were of ¾-in. plate, and the furnace nozzle in each head was flanged outwardly.

The combustion chamber was formed by extending the shell plate beyond the rear head a sufficient distance to provide ample space for the products of combustion to reach the 3-in. tubes, as is common to "dry-back" marine boilers, as distinguished from those having a "wet-back," or a combustion chamber entirely surrounded by water. In standard construction of this kind the rear head, or combustion-chamber nozzle, is flanged inwardly, which results in the nozzle and heads of the rivets forming the nozzle seam being exposed to the water contained by the boiler on one side and to the products of combustion on the other side. However, the construction of the boiler in question, indicated in Fig. 3, offered no cooling agency, as the end of the furnace flue and shop head of the rivets were exposed to the temperature of the gases leaving the furnace, while the furnace nozzle flanges in the rear head and the factory head of the rivets were exposed to the temperature of the gases in the combustion chamber. These temperatures would be nearly alike and would vary considerably, depending on the rate of combustion, but with the boiler in service under pressure the gases must have been of sufficient temperature to heat those parts of the boiler greatly in excess of the limits prescribed by good practice.

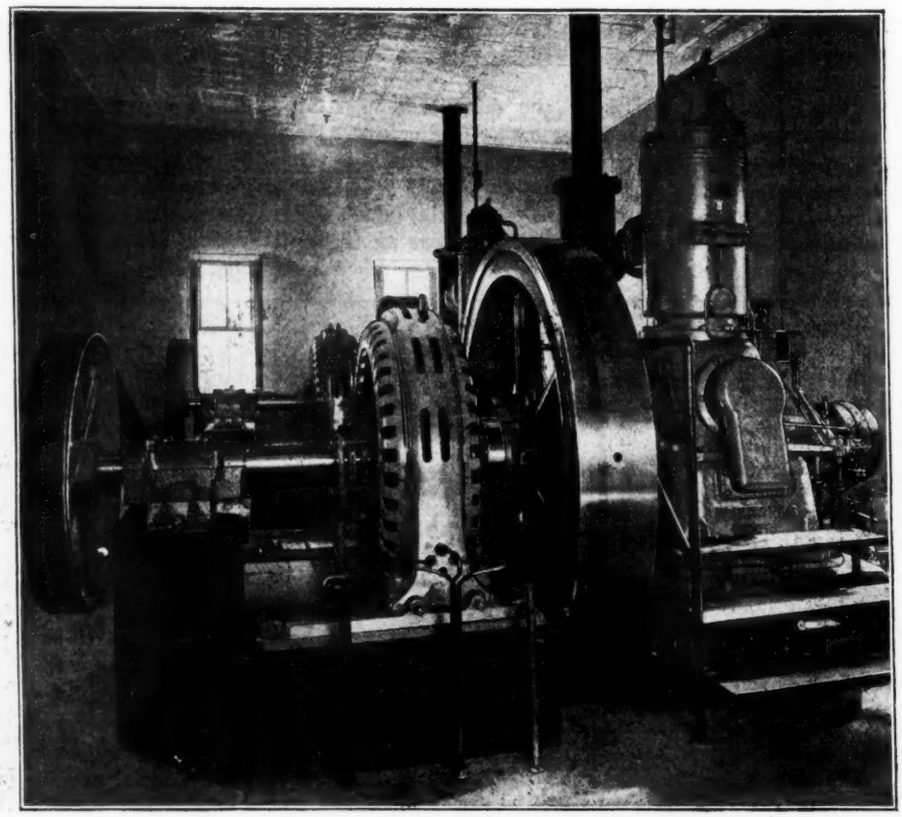
This continuous overheating could but result in weakening the material and in ultimate failure. Taking into consideration that the boiler had been designed for heating purposes, the length of time it had been in operation, the change in location and conditions of service, the pressure to which the safety valve was loaded—to say nothing of its size—and which pressure would be understood as the maximum carried, as well as the high temperature the rear head furnace seam must have reached, it is not necessary to look further to ascribe a cause for the explosion.

There is encouragement in the attitude of the officials of many states, who insist on a rigid inspection of new and second-hand boilers that form part of new installations and refuse to authorize the operation of boilers that do not meet the requirements of safety. As the Boiler Code of the American Society of Mechanical Engineers is adopted and enforced by additional states, doubtless the indiscriminate traffic in second-hand boilers of questionable condition will cease.

## Mine Coal But Use Oil Engine

Texas has always been the home of the unusual, and it will cause no surprise to learn that one of the most unique power plants in America is found in the Lone Star State.

The lignite coal mined in Texas is deficient in heating value and for this reason is sold at a low price. It is the general experience that this lignite slacks badly on being exposed to the weather and that its value



COAL-MINE POWER PLANT

decreases with the duration of weathering. The natural conclusion is that the most economical results can be obtained by burning it under boilers as close as possible to the source of supply; that is at the mine mouth.

This deduction fails to hold good in the case of the Strawn Coal Co., of Strawn, Tex. This company mines and ships lignite coal and is engaged in the electric light and power business in Strawn as well as in other activities. It has been found that it is more profitable to sell the lignite it produces and purchase fuel oil for its own power plant.

The power plant, as originally installed, consisted of two 50-hp. Fairbanks-Morse Type Y semi-Diesel oil engines direct-connected to two 40-kva. alternating-current generators. These two engines proved so successful that a third oil engine was subsequently installed.

The underlying motive that prompted the installation of the engines was their thermal efficiency, which was much higher than that of a steam plant. It actually was more profitable to sell coal and buy oil.

## Installation of Metal Conduit

By W. A. Hefner

The installation of conduit may be divided into two classes of work: concealed and exposed. In concealed work the conduit may be cast into the concrete building structure or run between walls, etc., and in most cases is installed when the building is being constructed. In this class of work the runs between two points can be made as short as possible and the bends should be as sweeping as conditions will permit as this will facilitate pulling in the conductors. The appearance is of secondary consideration as the conduit is all covered when the building is completed. In this kind of work fittings such as condulets, etc., are seldom used; all pipes are terminated in floor or outlet boxes. These boxes should all be secured so that they will be flat and square when the walls and ceilings are finished. The best way of securing these boxes is to fasten them to the building structure, and if this cannot be done boxes should be used with adjustable tops so that they can be made even with finished work. When laying the conduit, it is a good plan to make use of wooden plugs and as each piece of conduit is laid, to place a plug in it and remove it when the next piece is added. This prevents foreign matter from getting into the interior of the conduit and causing trouble when the wires are pulled in. It is also a good plan to put a plug in each pipe that ends in terminal boxes and leave it there until ready to pull in the conductors. Fig. 1 shows a main pull-box before the concrete was poured with conduits running

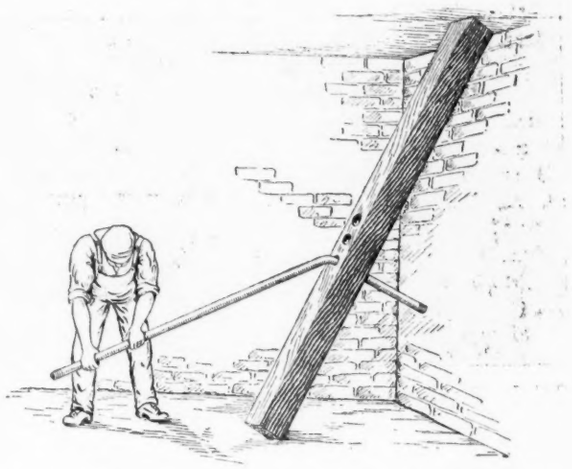


FIG. 4. METHOD OF BENDING PIPE LARGER THAN ONE INCH

into it and gives a good idea of the sweeping bends used on concealed conduits.

There are various ways of bending conduit, and the method used depends very largely upon conditions. Where there are large quantities to be bent, machines are frequently used that are made for this purpose. But in average construction work the hickey is usually employed for conduits from one inch diameter and smaller. The device is easily made, as shown in Fig. 2, with a tee-fitting of a size that will easily slip over the conduit to be bent, mounted on a piece of pipe about five feet long, the latter serving as a handle. Patent hickeys are made, but in general the tee-fitting will serve the purpose effectively. The method of using the hickey is shown in Figs. 2 and 3, either way being generally considered as equally good practice.

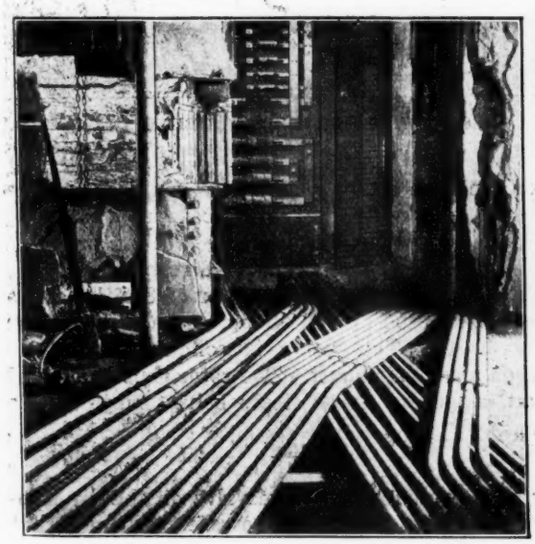


FIG. 1. CONCEALED CONDUIT AROUND PULL-BOX BEFORE POURING OF CONCRETE

FIG. 2. BENDING PIPE WITH A HICKEY

FIG. 3. ANOTHER METHOD OF USING THE HICKEY

For larger conduit, up to say 2 in., either of the following methods can be used: As shown in Fig. 4, a 4 by 6 timber may be employed, with holes bored through it of a diameter to take the different sizes of pipe to be bent. The timber is of a length to reach from the floor to the ceiling at about a 20-deg. angle, so that the top will rest against the post or a wall. A structure may be

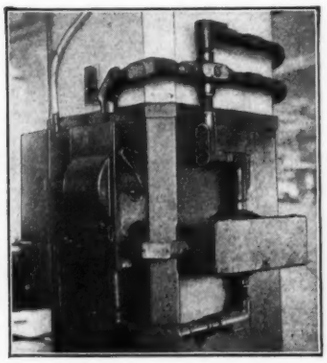


FIG. 5. SHOWING USE OF TOO MANY FITTINGS

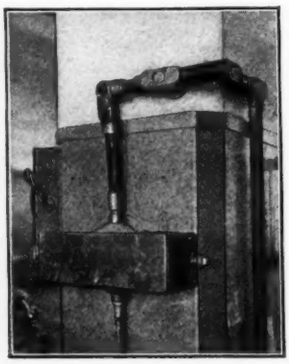


FIG. 6. SHOWING CORRECT USE OF FITTINGS

built up of 3 x 4-in. scantling, using two pieces as uprights and two for crossbars, one placed on each side of the two uprights, located and nailed or bolted in place. A piece of 2 by 4 is fastened across the top of the uprights, as a support and spacer. With the devices that are indicated in Fig. 4 it is necessary to work the conduit gradually through as the 90-deg. bend is made, since the pipe will strike the floor if bent vertically downward. The foregoing methods for bending conduit are used either for exposed or for concealed work. In some cases it is better to use standard 90-deg. elbows than to bend them; this is a condition determined by circumstances. In exposed work the main points are placing conduit safe from mechanical injury and making the installation so as to have a neat and workmanlike appearance. The first is a matter regarding which few suggestions can be made since it is regulated by conditions; that is, if around a machine, it must be kept out of the way of moving parts, and if for building feeders and lighting circuits, the conduit must be placed so that it is not liable to be hit by heavy articles, doors or other objects.

In exposed work fittings may be used, of which there are many makes and types. The use of fittings is often overdone, as shown in Fig. 5. The same ends are accomplished in Fig. 6 as in Fig. 5, but the former costs less and has a better appearance as well as showing the skill of the workman. Where bends can be used without danger of bringing work in the range of mechanical injury, it makes a better-looking job and is also cheaper.

## Germany Building Large Steam Turbines

Rapid strides are being made in the erection of large power stations upon the vast lignite deposits in central Germany. As prime movers turbines are principally employed, and these are of exceptionally large dimensions in the case of the Goldenberg-Werk, a sub-works of the Rhenish-Westphalian Electricity Supply Co., near Cologne. These turbines, built by the Allgemeine Elektricitäts Gesellschaft, are designed for an output of 60,000 kva. at 1,000 r.p.m. The voltage of the alternator is 7,000. A steam pressure of 170 lb. per square inch is used, the temperature being 617 deg. F. Two condensers are attached to the machine, each of a cooling-surface of 32,000 sq.ft., giving a temperature of the cooling water of 80.6 deg. F.

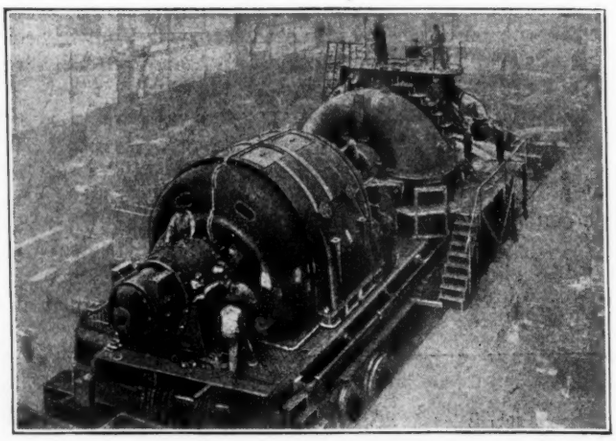
The weights of the main parts of the turbine are: Turbine complete, 250 tons; rotor, 49 tons; generator complete, 225 tons; generator rotor, 106 tons; condenser, 100 tons.

Great difficulty was encountered in shipping the equipment on account of its vast bulk, and a special truck had to be designed and built in order to insure safe transit of the alternator rotors.

Ten runner wheels are provided in the turbine, one double-bladed for high pressure and nine single-bladed for low pressure. The diameters of the wheels are 133.9 to 149.6 in., the circumferential velocities being 590 to 655 ft. per second at 1,000 r.p.m.

The blades were made from one piece of high-grade steel. The diameter of the bearing surfaces of the rotor is 23.6 in., the circumferential velocity being 100 ft. per second. Two steam exhausts of a diameter of 98.4 in. each are provided with the turbine, each condenser having a separate outlet for exhaust steam.

The turbine is built upon the A.E.G. standard design, three main bearings being provided, of which the center bearing has been developed as a double bearing so as to reduce the unit bearing pressure. The two rotors are connected by a rigid flange coupling mounted between the bushes of this center bearing. The large dimensions of the turbine necessitated close attention to heat



60,000 K.V.A. GERMAN TURBINE

expansion, and the center foundation was used as support for the longitudinal expansion. The connecting steam pipe is so designed as to allow free expansion of the casing of the machine in either direction.

The alternator rotor has a diameter of 86.6 in. and a circumferential speed of 380 ft. per second. The total length is 30 ft. This rotor is composed of plates arranged on a common shaft. The rotor thus assembled underwent a severe speed test, being subjected to 500 r.p.m.

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If the high-pressure discharge valve on the air compressor becomes too hot, it can be safely assumed that it is leaking. The air leaks back and forth through the valve, increasing in temperature at each compression.

# EDITORIALS

## Coal Contracts That Mean Something

THE American Gas Association is urging its membership that they do not enter into coal contracts for the coming year without having proper provision made for enforcement of delivery under all reasonable conditions. Particularly this association objects to having the gas companies enter into coal contracts that apply penalties to only one party, the purchaser. It also stresses the necessity for requirement of delivery under contracts using the following language:

> It should be provided that the coal producer will sell no spot coal nor make sales to casual or temporary customers until he has satisfied in full the term contracts for which he has assumed obligations.

If this association can bring about the formulation of contracts such as it urges, it will certainly have accomplished much good for the purchasers of fuel.

Under the recent Supreme Court decision in the case of Producers Coke Company versus McKeefrey Iron Company, it appears that this court would confirm the District Court findings that failure to deliver under contracts because of car shortage is not adequate ground for relief from penalty and damages when sale in the spot market at enhanced prices is being practiced instead of making deliveries on contract to the maximum degree possible. Although the Supreme Court simply declined to review the case, this in effect confirms the decision of the lower tribunal. It also makes it unlikely that purchasers of contract coal need fear that they will remain helpless when high spot prices offer unusual temptation to the producer to forget his contract obligations, as has so often been the case during the past season.

Power-plant executives who are charged with keeping power costs to the minimum can well urge upon the department responsible for fuel purchases that they take the advice of the American Gas Association with respect to the type of coal contracts that they undertake to secure. The purchaser will thus be much less likely to find himself embarrassed by high costs through the necessity of buying coal in the open market when he has expected to be amply provided for by contract deliveries.

## Test Code for Steam Engines

THE test codes of the American Society of Mechanical Engineers are under revision, and considerable space has been devoted in this issue to presenting the tentative draft of the new Steam Engine Code for discussion, suggestion and criticism. It has been reduced to the form presented by a committee of specialists and will be submitted to the society for approval or adoption at the spring meeting in Chicago in May. In the meantime there is opportunity for reconsideration and revision.

One of the things that occasioned the most discussion in the committee was the elimination of any directions for computing or any place for recording the "steam accounted for by the indicator." This was condemned by certain of the members as liable to misinterpretation, and a case was cited where the sellers of an engine which did not approach the guaranteed performance were able to get the "steam accounted for by the indicator" accepted as the real steam rate, because it was approved by the A. S. M. E. Code.

If such a case is on record, the purchaser must have had a fool lawyer and the seller a complaisant judge. The veriest tyro in the subject knows that there is a great difference between the amount of steam fed to an ordinary engine and that accounted for by the indicator, this difference being the cylinder condensation.

Nobody attempts to even approximate the actual water rate of an engine by multiplying the cubic contents of the cylinder up to a certain point by the number of times that this volume filled per hour, and the weight per cubic foot of steam at the pressure shown by the indicator to exist at that point. Paul Clayton, in a paper presented to the American Society of Mechanical Engineers in May, 1912, pointed out that the shape of the expansion line of the indicator diagram depended upon the amount of water in the cylinder at the point of cut-off, and that by determining the exponent of that curve a fair approximation might be made to the actual water rate. The possibilities of this method were never exhausted, but that is another matter. The "Steam accounted for" is out of the Code, but there is no penalty against its use for what it is worth by those who wish to use it.

Another matter that occasioned discussion still in progress is that of engine efficiencies. The unparticular were—and still are—wont to speak of the ratio of the amount of work actually accomplished by the engine to the work that could have been accomplished by an ideally perfect engine working the same steam through the same temperature range on a Rankine cycle, as the "Rankine efficiency" of the engine or turbine. But the writers of books and the "clear thinkers" say that Rankine efficiency really means or is likely to be confused with the efficiency of the Rankine cycle; that is, the ratio of the amount of heat that could be converted into mechanical energy when worked through the Rankine cycle to the total amount of heat furnished. This is output-input relation and properly an efficiency. The former is the ratio of two efficiencies, the efficiency of the Rankine cycle for the range and quality in question and the thermal efficiency of the engine. It is properly not an efficiency, but a ratio of efficiencies, and has come to be referred to in standard literature here and abroad as the "Rankine efficiency ratio" of the machine under review. The committee at first proposed to reduce this to "the efficiency ratio" to sidestep the conflicting claims of Rankine and Clausius to credit for the discovery of the cycle. The quantity in question is an efficiency ratio but not *the* efficiency ratio; there are others. In consequence of discussion at the last meeting, however, the term was changed to "machine efficiency," which has called out remonstrances

from even more sources than the change at first proposed.

Numerous other changes have been made from the code of 1915. In your opinion are they commendable? In this period of revision an opportunity is offered for the incorporation of new material and the embodiment of new ideas. Will you not let the committee, the society, the profession have the benefit of your concentrated attention, to the end that the Steam Engine Code when adopted shall represent the best thought and experience of the steam-engineering profession in America?

## The Proof of the Pudding

THERE is a good old English adage to the effect that "The proof of the pudding is in chewing the string." In *Power* for Nov. 2, 1920, was an editorial entitled "Why Exempt Oil-Country Boilers?" which briefly reviewed a situation familiar to those who have followed the fight of some gentlemen connected with oil-field interests, against the adoption of the A. S. M. E. Boiler Code for oil-fired boilers that are used in the oil country.

Another editorial on the same subject, published on Nov. 23, 1920, concluded as follows:

> The treatment of existing installations must not be so drastic as to put out of commission a lot of boilers which, while not so immune from explosion as the Code boiler, have a fair chance, with good supervision, to put in yet a few years of usefulness. This treatment will require tact on the part of the Board and vigilance and skill on the part of the inspectors. These old boilers will work themselves off in a generation. As a matter of expediency, legislators, in adopting boiler-inspection laws and inspectors in enforcing them may have to tolerate for a time the risk of murder and suicide upon the part of the adherents of the cheap boiler for use in sparsely settled districts in order to secure protection for the public in more congested parts. But the matter will eventually work itself out. If the cheaper boilers do not explode, if the provisions of the Code by which they are disqualified are proven to be uncalled for and unnecessary to safety, the Code will have to be modified in these respects. If, on the other hand, they do continue to explode and it can be shown that their explosion is due to the failure of their makers or users to comply with the requirements of a safe boiler as defined by this board of recognized authorities, any court will ascribe their explosion to wilful negligence, and the damages and opprobrium may be more onerous than compliance with approved practice.

The gentlemen referred to will undoubtedly be interested in the description published in this issue of an explosion that recently took place in Ohio, where oil-field boilers are exempt, and which caused the death of one man and the serious injury of another. Taken in connection with the explosion (also in Ohio) described in the issue of December 21st last, it would seem that the statement to the effect that "oil-field boilers do not explode" should, to say the least, be taken with reservation.

In view of the claim made by objectors that the adoption of the A. S. M. E. Code would work unnecessary hardships on the owners of boilers now in use, attention is called to paragraph 394 of the Code, which reads as follows: "No valve of any description shall be placed between the safety valve and the boiler," etc.

As shown in the illustration this boiler was operated with a stop cock between the shell and the safety valve, and the stop cock was found closed. Without entering into any question of construction at all, therefore, it is evident that if this boiler had not been exempt from the Ohio law, and had been inspected and operated in accordance with it, this accident, with its attendant loss of life and damage of property, would not have happened. How long will the exemption-for-oil-field gentlemen continue to chew the string?

## Testing Relays

MODERN electric-power systems with capacities ranging into hundreds of thousands of kilowatts and networks of parallel and loop circuits have been made possible only by the development of proper protective devices. In the various schemes of protection the relay may be considered the brain, since its function is to detect any disturbance in the system and operate the necessary devices to relieve this disturbance with a minimum of interference to the continuity of service, in case the trouble should be serious enough to warrant removal.

It is evident, therefore, that the importance of thorough and frequent inspection and testing of protective relays cannot be overemphasized. The cost of the damage that may be caused in case a relay fails to function when trouble occurs on a system, even one of small capacity, makes the cost of regular inspections and tests fade into insignificance. In making these tests, no general rule can be laid down; methods will be determined largely by local conditions. However, the article in this issue, "Testing Alternating-Current Relays," by Victor H. Todd, will be of assistance in making such tests.

As pointed out by Mr. Todd, if possible the preferred way of testing a relay is to apply load on the primary side of the current transformer until the protective equipment operates; but this is generally not practical and some method such as suggested in the article must be resorted to. Although testing a relay by applying load to the equipment will show whether all parts of the protective equipment are operative, it is not a guarantee that the protective apparatus will function in times of trouble. Probably what is far more important is careful inspection and cleanliness, and by actual test to know that the circuits are complete. A relay may operate once and trip the switch, but unless the parts are kept clean dirt may get into the contacts and prevent it from operating a second time. Since the integrity of the tripping circuit is an all-important part of the protective system, it is essential that the operator know that this circuit is alive right up to the relay contacts, If this is known, as can be determined by a pilot lamp, and the relay is kept clean and operative as well as the tripping device on the switch, it is about the best assurance that the protective apparatus will function as a whole when trouble occurs.

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Do we gain by experience? Apparently not if we are to judge from some present-day conditions. We have seen many branches of the power industry grow up through a series of manufacturers' petty jealousies, personal prejudices and cutthroat methods, with many disastrous effects before the industry emerged on a sound foundation. Yet with the bad effects of past methods as a warning, old practices are being carried on by some of those in branches of the power industry at present under development. Is it not about time that we learned that more is to be accomplished by co-operation than by knocking?

# CORRESPONDENCE

## Does a License Law Help?

I have read Mr. Shaw's letter in the Oct. 12 issue and the criticism by Messrs. Carter, Reid and Jennings, and although these men have made statements that in themselves are correct, none of them has struck the meat of the situation.

It must be admitted that any law that is put on the statutes for the purpose of promoting public safety is a good law. It must also be admitted that boiler-license laws are the result of a desire to protect the general public by putting competent men in charge of power-generating plants.

If the law itself is good and justifiable and the benefits derived therefrom are undesirable in any way, it must be because of lack of proper enforcement; and all engineers who are thoroughly familiar with the license laws of various states and communities will agree that it is in the manner of enforcement that the law fails of its primary purpose.

In the State of Massachusetts it is well known that in recent years the Board of Examiners, who are delegated to grant licenses to engineers in that state, have distributed those licenses impartially without fear or favor. At the same time they have kept their requirements almost uniformly stringent, with the result that Massachusetts is reputed to have a greater percentage of thoroughly competent and well-informed operating engineers than perhaps any other state or community in the United States. Another result has been—just as one of the correspondents stated—to increase the standard of remuneration paid engineers in Massachusetts to a figure considerably above what is paid in almost every other part of the country.

On the other hand, I could cite states and cities having engineer's license laws where the licenses are distributed in such a lax and unfair manner as to neutralize the benefits that should be derived from such laws, and in that respect I refer to benefits not only to the public, but to the engineers themselves.

It is my opinion that the sooner the real stationary engineers of the country get behind those who are making efforts in the various states to promote license laws and help put these laws through and use their influence to see that the laws are fairly and efficiently enforced, the sooner will the steam-power-plant operating engineer rise to the place which he deserves to occupy among the country's leading engineers, and the sooner will his remuneration be proportionate to the amount of knowledge and experience with which he must be equipped to succeed. A. J. LAMIE.

New York City.

## Steam Making With Fuel Oil

In the Dec. 14, 1920, issue, page 935, is an article, "Steam Making with Fuel Oil." I witnessed the tests of Jan. 9 and 10 and Jan. 23 and 24, and was retained as consulting engineer by the oil company which sold this mill the oil under a year's contract and which also installed the oil-burning equipment used.

The writer of this article closes with the statement: "No higher efficiencies are ordinarily obtained with fuel oil than prevail in coal-fired plants. The use of oil increases the boiler and setting repairs and therefore interferes with the mill operation to a greater extent than would coal." I object strenuously to both of these statements as being very much in error.

This plant was in a deplorable condition, and the change from coal to an oil-burning installation, was done with a view to least expense and the possibility of going back to coal at the termination of the oil contract. In consequence this was not an oil-burning plant, but a coal plant burning oil.

Then to add insult to injury, the settings of the boilers were in bad condition and the infiltration of air made it impossible to get anything but the poorest of results, as seen by the $CO_2$ readings taken during the test, which read as follows: 9.0, 7.8, 9.2, 7.4, 9.4, and 4.9 per cent. For some reason these were not published in the boiler-tests report.

In *Power* of Oct. 5, 1920, page 528, an article was published showing a daily log sheet of a modern California oil-burning steam plant with an average efficiency of 80.7 per cent. As there are many plants in operation in this country showing equally good daily results, it seems strange to draw such a conclusion as has been drawn by the author of the article under discussion. Why draw conclusions from old worn-out junk where the boilers are so old that tubes let go if forced above rating and where the settings and furnace linings were in such miserable condition?

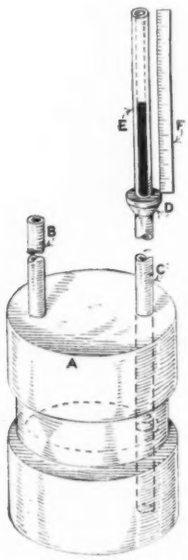
As to the maintenance of oil-fired water-tube boilers, there are hundreds on the Pacific coast that have been operated continuously from 150 to 175 per cent of rating for periods of five years without renewing any tubes and with a very small amount of furnace attention.

I think it up to *Power* to investigate the conditions at this plant and then publish the real facts in order not to mislead people along the Atlantic coast. It makes no difference to engineers out here, for the results obtained from oil fuel are too well known to be biased by such an article. GEORGE S. BLANKENHORN.

San Francisco, Cal.

## Home-Made Water-Level Indicator

Recently wanting a gage to show the water level in an overhead tank and not having a suitable dial gage at hand, we devised one as shown, which is essentially a U-tube with water in one leg and mercury in the other. A ¼-in. pipe *B* is tapped into the bottom of the tank and led down to the reservoir *A*, which is made of a 2-in. pipe 3 in. long and capped at each end. The end of the pipe *B* should be just flush with the inside of the cap, to avoid air pockets. *C* is a ⅛-in. pipe screwed through the top cap and reaching almost to the bottom of *A*. *D* is a special fitting turned out by the plant machinist and is threaded to screw on the pipe *C* and to take the gland nut for a half-inch gage glass *E*, which is packed at one end only, the top end being open to the air. *F* is the scale, which should be calibrated in place by actual measurement of the water in the tank. After it is assembled, mercury is poured into *A*, and the gage is ready for operation. The length of the pipe *C* depends on the distance from the gage to the bottom of the tank, and the length of the glass *E* depends on the depth of the tank itself. The gage need not be mounted directly below the tank, but may be placed at the fireman's desk or at any other desired location. It has the further advantage that it can be calibrated to read in inches of water in the tank or in any other reading that is desired.



WATER-LEVEL INDICATOR

Wichita Falls, Tex. L. R. GRAY.

## Something About Steam Traps

Steam traps are probably one of the most prolific sources of waste about a plant unless proper attention is given them. When a trap is installed, a tee with a nipple and valve should be connected between the trap outlet and the check valve, so that when making inspections it will only be necessary to open the valve to determine if steam is being wasted through a leaky or improperly adjusted valve. When making this test, it should be remembered that a portion of the condensate in passing the trap will flash into steam when the pressure is reduced and that the drip from a properly adjusted trap will show some vapor. If the drip shows any considerable amount of steam, the valve should be examined, or if the trap is adjustable, as are some of the thermostatic types, an adjustment should be made so as to allow no live steam to pass.

Many traps used on devices where the service is interrupted become airbound when steam is again turned on, and will not work until the air is removed. A satisfactory way of relieving this condition is to tap the top of the trap and screw in an automatic air valve of the type used on radiators. This will relieve the air at once and save the engineer a lot of trouble. It is generally the custom to install a bypass around a trap, presumably for the purpose of using it as a substitute in case the trap fails to operate or must be removed for repairs. Of course this is necessary in some cases, but as a general rule it is better to have a spare trap on hand with which to replace the defective one, as bypass valves have a remarkable tendency to open themselves, as the following will illustrate:

An institution engineer, when inspecting the traps on the kitchen equipment, invariably found some of the bypass valves open, but of course no one knew how they got that way. In order to reduce the waste, he placed a sheet-iron disc with a very small hole in it in the bypass union. To his surprise, upon opening one of these unions a few weeks afterward, he found the disc gone and the valve wide open. On examination, several others were found in the same condition. The blame could not be placed exactly, but the mechanically inclined cook was naturally given the credit. So the bypass was removed and no further trouble was experienced.

Norwalk, Cal. A. C. MCHUGH.

## Hot-Water Heating System

More than a dozen years ago a hot-water heating system was installed at the plant where I was chief engineer. The radiation was sufficient to heat the buildings when the circulating water was at a maximum of from 150 to 160 deg. F.

The exhaust heater was between the low-pressure cylinder and the condenser, and even in cold weather it was a rare thing to carry less than 18 in. of vacuum on the low-pressure cylinder. The live-steam heater was trapped and then discharged into a float-controlled return tank, not vented to the atmosphere, which supplied feed water at from 220 to 260 deg. F.

The live-steam heater was used at night, and the mill was heated sufficiently to warrant cutting down the circulating-water temperatures when the engine was started. But even though the rooms were 72 deg. F. in the cold weather and I felt that we had a model heating system, the workmen "kicked." They said that the pipes were not hot, and they even got the agent talking along the same lines. Thus, this system was practically condemned because it was installed for low-temperature circulating water and the pipes were not "hot" enough to suit the help.

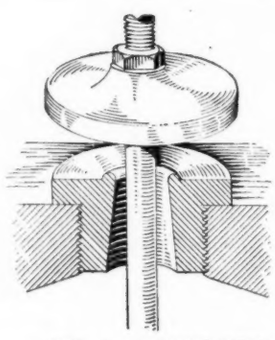


FIG. 1. LARGE DISC, SMALL SEAT

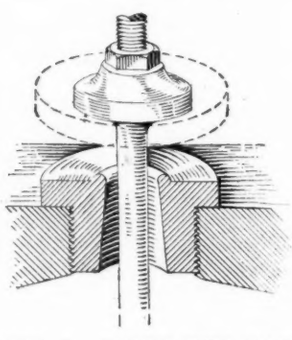


FIG. 2. VALVE DISC MADE SMALLER

We saved a large amount of fuel by this system, and it really was a very economical one. A similar layout is now recommended, but the turbine is substituted for the reciprocating unit. It was no uncommon performance during spring and autumn to run a 24-in. vacuum on the engine. The heater acted as a surface condenser.

I have had hot-water heating systems in other plants since the one mentioned, but have used low-pressure steam and the maximum temperature of circulating

water was approximately 200 to 220 deg. F. Hot water is a remarkably flexible heat, and the saving in spring and fall, when a mild heat is required, is considerable.

If a system of thermostats is installed, the engineer in charge of the heating where hot water is employed has an ideal plant.

A case of theory and practice came to my attention lately. A valve in a certain kind of trap was declared to be too large for the pressure carried, so another valve and seat were sent to take its place. The new equipment had the same identical valve, but a smaller seat, as shown in Fig. 1. The valve seat proper was raised, and apparently the theory held forth that steam, which is above the disc, would get under the disc and balance the valve to a large extent.

When the valve opened and steam rushed past the seat, it had the same effect on the large valve disc as on the increased area of a pop safety valve. The valve refused to reseat, and the mechanism was not powerful enough to effect this action.

After the disc was turned to the proper size, as in Fig. 2, the trap worked all right. L. W. PETERS.

New York City.

## Under the City Sidewalks

Several years ago a steam boiler under the sidewalks of a street in New York City exploded, completely wrecking the sidewalk in the immediate vicinity. Many persons were doubtless astonished to learn that boilers

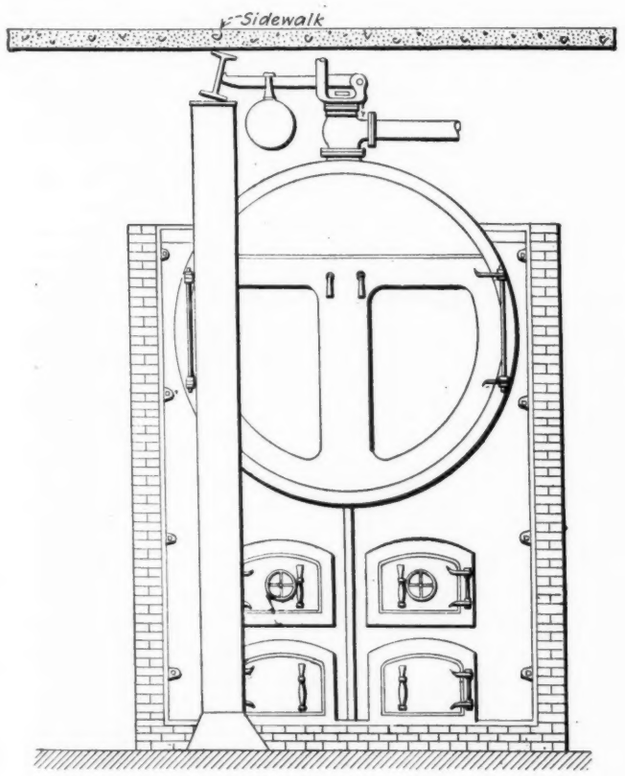



FIG. 1. I-BEAM TILTED AGAINST VALVE LEVER

are placed under city sidewalks, but it is a common practice and if pedestrians knew of the large number of boilers carrying high steam pressure that are so located they would not feel as secure as they do when walking along in apparent safety.

There was recently brought to the attention of a boiler-insurance company a case that shows the necessity of engineers and inspectors paying particular attention to what is going on over the boilers of which they have charge and are to inspect. In this instance a 52-in.

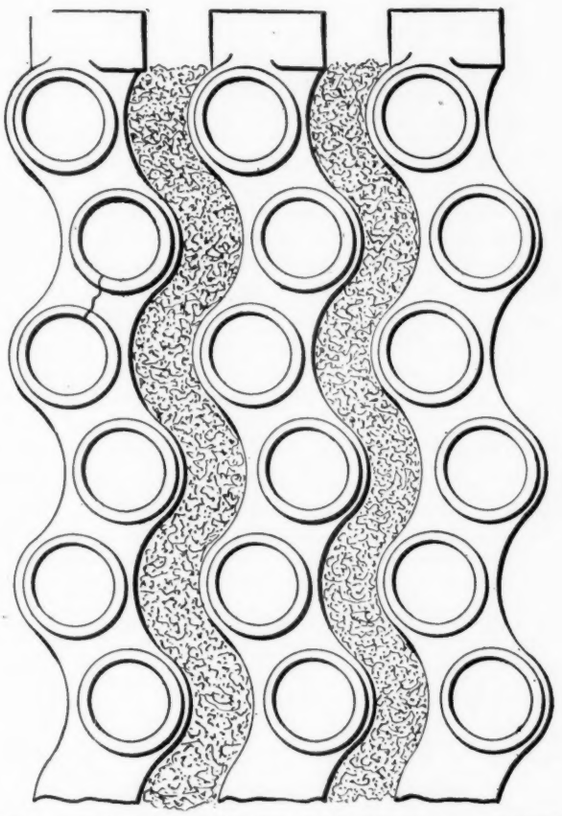


FIG. 2. ASBESTOS FILLING BETWEEN TUBE HEADERS MAY CAUSE CRACKS

by 18-ft. return-tubular boiler was placed under the sidewalk, running longitudinally with it, with scant headroom between the boiler and the girders supporting the sidewalk. An I-beam ran horizontally above the boiler, supported by pillars at each end and so placed that it just cleared the lever of the ball-and-lever safety valve on the boiler. A recent inspection by a boiler inspector showed that the I-beam had become tilted as shown in Fig. 1, the angle being such as to block the safety-valve lever and effectually preventing it from operating at the blowing-off pressure.

How long this condition had existed is not known, but it is the third occurrence of the kind that has come to the attention of the boiler-insurance company and emphasizes the fact that, although the clearance between the boiler and the ceiling or sidewalk may be scant and make it a disagreeable job for the engineer to go up over his boilers for inspection, he should do so.

Another thing that an engineer should watch, although it has nothing to do with under sidewalk installations, is the asbestos packing that is placed between the headers of some types of water-tube boilers. As is well understood, the spaces between the tube headers are packed with asbestos, which in time becomes extremely hard. In fact a case recently came to the attention of the boiler inspector in which it was necessary to use a cold chisel to remove the packing, which seemed to be as hard as flint.

It is easily seen that under such a condition there is no opportunity for the headers to expand with the heat, and as a result, quite a number have been found with cracks between the tube holes, as shown in Fig. 2. It is assumed that the solid condition of the asbestos was the cause. The remedy is, of course, to remove the packing as soon as it begins to harden.

New York City. O. W. WARREN.

## Data on Motor Operation

In an industrial plant manufacturing a product of a textile nature, there are in use about 400 three-phase squirrel-cage induction motors ranging from 1½ to 15 hp., operating at speeds of 900 to 1,800 r.p.m. We find the average rewinding cost per motor per year to be about $8, and this seems too high since our other plants average about $3.70 per motor per year. Can readers of *Power* advise what is considered best practice as to bearing maintenance, frequency of oiling and cleaning of bearings, grade of oil to be used and the life of ring-oiled bearings under average operating conditions?

It is considered practical to use one grade of oil for all sizes and speeds, and where motors are protected by double inverse-time-limit overload coils only, no fuses being employed, at what percentage of full-load current should they be set for? Under these conditions, where remote control is used, what means can be taken to provide against single-phase operation and what should the rewinding charge per motor per year amount to? M. KING.

New York City.

## Tables of Physical Properties of Various Refrigerants and Steam

Physical data are arranged in tables for convenience in use and to be of maximum value. Therefore such tables should be arranged for maximum convenience of those for whose use they are formulated.

Engineers now have available several tables each of the properties of the saturated vapors of water, ammonia, carbon dioxide, sulphur dioxide, methyl chloride and ethyl chloride, not to mention other media which have been employed and proposed to be employed as refrigerants. No two of these tables, so far as the writer is aware, include exactly the same kind of data arranged in the same order under any uniform system of captions and symbols.

The United States Bureau of Standards is now formulating tables of Properties of Ammonia in the saturated and superheated regions. That covering the saturated region has already been submitted in a tentative form to the American Society of Refrigerating Engineers.[1] Since it is through the direct efforts of that society that funds are being provided for the completion of the work of making the final observations and computations necessary to complete these ammonia tables, it may be assumed that the tables will be presented in the form that will be most convenient for the use of the refrigerating engineer, provided such form can be determined in advance. The present time seems most propitious therefore to invite suggestions from engineers and others in an effort to arrive at the most practical form.

In order to have something from which to start the writer has compiled the following outline of the classes of data and subheads that appear variously contained and variously arranged in a number of tables that have recently come to his attention. This list, as will be noted, includes thirty heads, which would obviously be too many columns to be convenient for practical engineering use. The writer has therefore indicated by a * certain data which, in his estimation, should be included in a brief table for every-day use. These nine items have been arranged in the order that seemed most convenient. Whether this table should include entropy or not is problematical.

The general confusion existing regarding symbols is a matter that should be settled at this time. If the symbols adopted could be international, the results would well be worth striving for. To that end the widest publicity and freest comment is hoped for.

OUTLINE FOR TABLE OF PROPERTIES OF STEAM, AMMONIA AND OTHER REFRIGERANTS

Conditions
1. Temperatures
   1. Absolute C. Te
   2. Absolute F. Tf
   3. C. tc
   *4. F. tf
2. Pressures
   1. Absolute kg. per cm.²
   2. Absolute lb. per sq.in.
   3. Gage kg. per cm.²
   *4. Gage lb. per sq.in.
   5. Inches of mercury
   6. Mm. of mercury
3. Heat
   1. Heat of liquid cal. per kg. above —40 F. and C.
   2. Heat of liquid B.t.u. per lb. above —40 F. and C.
   3. Latent heat of vaporization, cal. per kg.
   *4. Latent heat of vaporization, B.t.u. per lb.
   5. Total heat of vapor, cal. per kg. above — 40 F. and C.
   *6. Total heat of vapor, B.t.u. per lb. above — 40 F. and C.
   7. Internal heat of vapor, cal. per kg. above — 40 F. and C
   8. Internal heat of vapor, B.t.u. per lb. above — 40 F. and C.
   9. External heat of vapor, cal. per kg. above — 40 F. and C.
   10. External heat of vapor, B.t.u. per lb. above — 40 F. and C.
4. Weights (specific)
   1. Liquid, weight of, kg. per cubic meter
   *2. Liquid, weight of, lb. per cu.ft.
   3. Vapor, saturated weight of, kg. per cu.m.
   *4. Vapor, saturated weight of, lb. per cu.ft.
5. Volumes (specific)
   1. Liquid, volume of, cu.m. per kg.
   *2. Liquid, volume of, cu.ft. per lb.
   3. Vapor, saturated vol. of, cu.m. per kg.
   *4. Vapor, saturated vol. of, cu.ft. per lb.
6. Entropy
   1. Liquid
   2. Vapor

A proposed form for abbreviated table comprising the items designated is as follows:

PROPOSED STANDARD ARRANGEMENT OF HEADINGS FOR TABLES OF PROPERTIES OF SATURATED VAPORS OF WATER, AMMONIA AND OTHER REFRIGERANTS

| Temp. Deg. F. (tf) | Pres. Lb. Gage (p 9) | Heat of Liquid Over −40 (.....) | Latent Heat of Vaporization (b.....) | Heat of Vapor Above −40 (.....) | Wt. of Liquid Lb. per Cu.Ft. (.....) | Vol. of Liquid Cu.Ft. per Lb. (.....) | Wt. of Gas Lb. per Cu.Ft. (.....) | Vol. of Gas Cu.Ft. per lb. (.....) |
|---|---|---|---|---|---|---|---|---|

New York City. C. F. MATTHEWS.

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Preignitions in the modern two-cycle engines cannot occur if the atomizer nozzle does not leak. The injection point is fairly late, and no oil is in the cylinder to ignite until practically dead center. If the atomizer leaks, oil will enter the cylinder early in the compression stroke and preignite. If the engine fails to burn all the fuel, at times part remains in the bulb to ignite on the next compression stroke.

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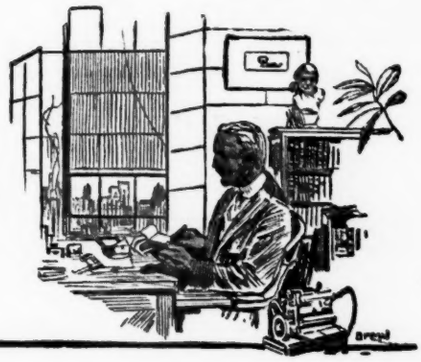
In repacking pump plungers, remove all the old packing. Never attempt to replace the old material; it is merely filling the stuffing box with material that has no oil-sealing qualities.

[1] See page 96 of this issue.

# INQUIRIES OF GENERAL INTEREST



**Oil Engine Fails to Synchronize**—Why do my oil engines refuse to synchronize? R. N.

In many cases the coefficient of fluctuation in an oil engine is such that the variation in the flywheel velocity is entirely too great for the generators to stay in step. Using heavier flywheels or a squirred-cage winding on the pole face will eliminate the trouble.

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**Sparking with Too Strong Interpoles**—What would be the effect of too many turns on the interpoles of a direct-current machine? R. A.

The object of the interpole is to produce a magnetic field which causes the current in the coil under commutation to reverse and build up in the opposite direction. If the field is too weak, the reversal will occur too late and there will be sparking; if it is too strong, the reversal will come too early, the current will build up to too high a value, and will have to be suddenly reduced as the commutator bar passes out from under the brush, and there will also be sparking.

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**Copper-Wire Gaskets for Flange Joints**—How are wire gaskets made and used for flange joints of steam pipe lines? W. C.

For medium-sized flanges and moderate pressures wire gaskets usually are made of soft copper wire $\frac{1}{16}$ to $\frac{3}{16}$ in. in diameter bent and joined to the form of a circular ring of appropriate size for placing them between the flanges inside of the bolt circle. The rings are readily formed by cutting them from a coil made by winding the wire around a mandrel to the form of a close spring and the cut ends of the wire are made continuous by a soft-soldered butt joint.

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**Efficiency of Induction and Synchronous Generators**—When a synchronous alternator and an induction generator operate in parallel, which is the more efficient? F. G. M.

If the two machines are of about the same capacity, the induction generator probably will show 1 to 2 per cent less efficiency. But it has many advantages such as sturdy construction and practically automatic operation, for the only attention or adjustment needed is oiling. It can never fall out of step or hunt even under the most extreme conditions of variable loading and frequency, is ideal for automatic hydro-electric plants and frequently is used with exhaust turbines for increasing the capacity of plants using reciprocating-engine units.

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**Determination of Ammonia in Calcium-Chloride Brine**—What is the best method of determining the presence of ammonia in calcium-chloride brine? R. L. B.

Nessler's reagent will prove satisfactory. This solution is made up as follows: 17 grams of mercuric chloride is dissolved in about 300 c.c. of distilled water to which is added 35 grams potassium iodine dissolved in 200 c.c. of water, constantly stirred until a slight permanent red precipitate is produced. To the solution thus formed add 120 grams of potassium hydrate dissolved in 200 c.c. of water; allow to cool before mixing. The amount is then made up to one liter by addition of water and mercuric chloride until a permanent precipitate again forms. After standing for a short time the solution is ready to be used. When a few drops of this solution are added to a sample of calcium-chloride brine or water in test tubes, if there is any ammonia present a slight coloration of the liquid will take place. A large quantity of ammonia will make the color still darker.

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**Relative Effect of Low- and High-Pressure Radiators.**—What is the relative effectiveness of dry room radiators supplied with exhaust steam at a pressure of 2 lb. gage and when supplied with live steam at 100 lb. gage? B. C.

When there is complete removal of air from the radiators and perfect circulation of steam, the heat radiated for a square foot of surface may be considered as directly in proportion to the difference of temperature of the steam within the radiator and the room temperature in the immediate vicinity of the radiator. Assuming, for instance, that the room temperature maintained near the radiator is 90 deg. F., as the temperature of steam at 2 lb. gage is 218.5 deg. F., and the temperature of steam at 100 lb. gage is 338 deg. F., then the relative effectiveness per square foot of radiation would be as (218.5—90) for the exhaust steam, to (338—90) for the steam at 100 lb. gage, or as 100 to 193.

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**Raising the Capacity and Power Factor of a System.**—We are planning to add a 1,500-kva. turbo-unit to our 3,000-kva. generating equipment, and also wish to install a synchronous condenser to improve our power factor, now only about 70 per cent. What should be the capacity of the synchronous condenser and the capacity of an exciter to supply both the new generating unit and the condenser? M. H.

Assuming that the condenser will not be used for power, but will operate under no load, and 100 per cent. power factor is desired; also that the power factor of the future load will remain 70 per cent:

The wattless kva. drawn by the load which the condenser must supply will be: $4{,}500 \text{ kva.} \times \sqrt{1 - 0.70^2} = 3{,}200$ kva. With 5 per cent. losses in the machine, your condensor capacity should be $\frac{3{,}200}{0.95} = 3{,}400$ kva. However, it is poor practice to attempt to bring the power factor above 90 per cent. when installing apparatus for this specific purpose, as the advantages gained in operating characteristics would not warrant the greater cost of a larger machine. The necessary capacity of a condenser to raise your power factor to 90 per cent would be,

$$\frac{4{,}500}{0{,}95}\left(\sqrt{1 - 0.70^2} - \sqrt{1 - 0.90^2}\right) = 1{,}320 \text{ kva.}$$

or little more than one-third of the capacity necessary to give 100 per cent power factor.

The current and voltage characteristics of the exciter suitable for any machine should be obtained from the manufacturer, but it is safe to roughly assume an exciter capacity of 3 per cent of full load for the generator and 4 per cent of full load for the condenser.

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[Correspondents sending us inquiries should sign their communications with full names and post office addresses. —Editor.]

# Power Test Codes

## A. S. M. E. Committee Appointed To Formulate a Test Code for Reciprocating Steam Engines Submits Preliminary Draft

IN 1918 the Power Test Committee of the A. S. M. E. was reorganized to devise and enlarge the Power Test Codes of the society, published in 1915. The committee is a large one, under the chairmanship of Fred R. Low, and under its direction are 19 individual committees of specialists who are drafting codes for the different classes of apparatus comprised in power-plant equipment. Below is reproduced the second of these codes to be completed, namely, the Test Code on Reciprocating Steam Engines. This code was prepared by a committee consisting of William C. Brown, chairman; Alexander G. Christie, secretary: George H. Barrus, Harte Cooke, Herman Diederichs, J. F. Max Patitz, and Fred H. Vose.

This committee will, of course, welcome suggestions for corrections or additions. These should be mailed before February 1 to the chairman, care of the American Society of Mechanical Engineers.

### Test Code on Reciprocating Steam Engines

#### Introduction

1. The code for steam-engine tests applies to tests for determining the performance of the engine alone (including reheaters and jackets, if any), apart from that of the independently driven auxiliaries which are necessary for its operation, and apart from that of feed-water heaters or other apparatus for reclaiming heat. For tests of an engine and independently driven auxiliaries combined with means for reclaiming heat (for example, a multiple-expansion engine from the receiver of which steam is withdrawn for heating feedwater or other purposes), the rules given in the Code for Complete Steam Power Plants should be followed.

#### Object

2. In accordance with the "General Instructions" the object of the test should be determined and recorded. If the object relates to the fulfillment of a contract-guarantee, an agreement should be made before the test between the interested parties concerning all matters about which dispute may arise, as noted in Par. 3 of the "General Instructions," and the points agreed upon should be stated in the Report of the Test.

#### Measurements

3. The measurements that must be made in a performance test of a reciprocating engine will consist of some or all of the following quantities

(*a*) The cylinder diameters and stroke.
(*b*) The volumetric clearance in per cent of the piston displacement.
(*c*) The diameters of piston rods and tail rods.
(*d*) The indicated horsepower.
(*e*) The brake horsepower or shaft horsepower output.
(*f*) The kilowatt output if engine is connected to a generator.
(*g*) The speed in revolutions per minute.
(*h*) The pressure in the steam pipe before the throttle.
(*i*) The barometric pressure.
(*j*) The percentage of moisture or number of degrees of superheat in the steam just before the throttle.
(*k*) The back pressure in the exhaust pipe near the engine cylinder.
(*l*) The receiver pressure.
(*m*) The temperature of the exhaust steam leaving all cylinders.
(*n*) The temperature of the drips if any, from jackets, reheaters and receivers.
(*o*) The temperature of steam leaving receivers, cylinder jackets, reheaters and similar parts.
(*p*) The weight of return drips from jackets, reheaters and receivers.
(*q*) The weight of the condensed steam in pounds or the weight of the water fed to boilers, less drips and leakage if the test is based on feedwater fed to boilers, less drips and leakage if the test is based on feedwater measurement.
(*r*) The temperature of the condensed steam.
(*s*) Engine-room temperature and outside air temperature.
(*t*) The variation in steam pressure in the steam chest.

#### Instruments and Apparatus

4. The instruments and apparatus required for a performance test of a reciprocating steam engine are:

(*a*) Tanks and platform scales for weighing water (or water meters calibrated in place).
(*b*) Graduated scales attached to the water glasses of the boilers if the feedwater is measured.
(*c*) Pressure gages, vacuum gages or mercury columns and thermometers.
(*d*) Steam calorimeters.
(*e*) Barometer.
(*f*) Steam-engine indicators.
(*g*) Planimeter.
(*h*) Tachometer, revolution counter or other speed measuring apparatus.
(*i*) Friction brake or dynamometer, if available.
(*j*) Appropriate electrical instruments if engine is connected to an electric generator.

Directions regarding the application, use, and calibration of these instruments and apparatus and statements as to their accuracy are given in the Code on Instruments and Apparatus.

#### Preparations

5. Before proceeding with an engine test Pars. 4 to 8 of the "General Instructions" should be carefully studied. The dimensions and the physical condition not only of the engine but of all associated parts of the plant, essential to the object of the tests, should be determined and carefully recorded. The following paragraphs suggest methods by which this information may be secured if required.

*Dimensions*

5a. The dimensions of engine cylinders should be taken when they are cold. If extreme accuracy is desired as in scientific investigations, corrections should be applied to the cold dimensions to conform to the mean working temperature. If the cylinders are much worn, the average diameter should be found. The clearance of the cylinders may be determined approximately from working drawings of the engine. For accurate work, when practicable, the clearance should be determined by the water-measurement method. To carry out this method, set the engine exactly on the center, with the piston at the end of the cylinder where the clearance is to be determined. From a quantity of water previously weighed pour enough into the clearance space by means of a funnel through some available opening, such as may be obtained by removing a steam valve in a horizontal four-valve cylinder, or through indicator cocks, until the clearance space is completely filled. By weighing the water remaining the amount necessary to fill the clearance space can be obtained, and by making the proper allowance for temperature the clearance volume may be calculated. The percentage of clearance is found by dividing the clearance volume thus found in cubic inches by the volume displaced by the piston in one stroke, also in cubic inches. Care should be taken to see whether the clearance space is so arranged that no air is retained when it is filled with water. If such pockets cannot be properly vented, this method will not give accurate results. When full, the gradual lowering of the water will show leakage by the valves or piston. Allow leakage to go on for a certain time, then from a quantity of water previously weighed pour enough into the clearance space to fill it up again, note the time it takes to do this and weigh the water remaining after filling up the clearance space. Then the weight of water from which clearance space is to be calculated ($W_1$) can be determined as follows:

$$W_1 = W - \frac{wT}{t - t_1}$$

where
$W$ = Weight of water filled into clearance space;
$T$ = Time to fill clearance space;
$t$ = Time allowed for leakage;
$w$ = Weight of water for filling space up again;
$t_1$ = Time required to fill clearance space again.

This method will give the proper correction to be subtracted if the leakage is not very great. If the leakage is too great, and the object of the test will allow it, the valves and piston rings must be put in proper condition.

The area of interior steam surfaces is all of that part of the interior of the steam cylinder, the piston head and the parts back to the valves that are exposed to the steam at the time that the exhaust valve is opened. If desired, the clearance surfaces can be calculated by subtracting from this interior steam surface the area of the circumferential walls of the cylinder from the location of the piston at the dead-end center to the location of the piston when the exhaust valve first opens.

*Leakage Tests*

5b. To determine whether the leakage of an engine is excessive or nominal, it should be weighed. This can be done in the following manner: In the case of a single-cylinder four-valve engine with a surface condenser, a cover or handhole plate on the bottom of the condenser is removed or a drip is tapped in the bottom of the condenser shell and, after turning on the circulating water, steam is allowed to pass into condenser until the condensate flows out of the opening in the bottom. Then the steam is turned off the engine and careful note is taken whether or not the flow of water stops, thereby testing the tightness of the con-

denser. (See Par. 6a for method of testing condensers for tightness when measuring condensate.) The engine should then be blocked just beyond the head-end center, with the valves in mid-position with full steam lap, the throttle opened and the leakage weighed for each minute for fifteen minutes or a half-hour, thereby determining the rate. This operation should be repeated with the engine just beyond the crank-end center. Each of these tests gives the leakage by one steam valve, one exhaust valve and the piston. If the leakage is only nominal no further leakage tests need be made, but if the leakage is excessive its source should be determined. In any case it cannot be assumed that such tests give an exact measurement of the leakage under operating conditions. They merely indicate the degree of leakage.

5c. In testing for the degree of leakage in the high-pressure cylinder of a compound engine the exhaust valves of the low-pressure cylinder, or the relief valves if they are connected to the condenser, should be opened to allow the leakage to pass. The low-pressure cylinder may be tested like that of a single-cylinder engine by admitting steam to it through the receiver and by-pass valve. Care should be taken when thus testing a compound engine that the pressure differences applied in both cylinders are approximately the same as the working pressure differences.

5d. If the engine has no surface condenser, a small one can be fitted up, or the leakage condensed by letting it flow into a barrel of cold water. If the engine is reasonably tight it may be assumed that the leakage should not exceed one-tenth of a pound per rated horsepower per hour, or one per cent of full-load steam consumption, so that the capacity of the small condenser or barrel of cold water need not exceed this amount.

5e. A method of testing for the degree of leakage of valves and pistons by observation in a four-valve engine, or an engine in which the admission valves can be worked by hand independently of the exhaust valves, is as follows: The engine is turned until the piston is about mid-stroke. The two steam valves are closed, the two indicator cocks are opened, and the full pressure of steam is admitted into the chest by opening the throttle valve. The starting bar is then moved first one way and then the other, closing first one and then the other exhaust valve, and the degree of leakage by the steam valves can be roughly judged by the force of the steam coming out of the indicator cocks. To test the exhaust valves and piston, the flywheel is blocked so that the piston will be at a short distance from the end of the stroke, and the steam is turned on. The leakage then escapes to the exhaust pipe, and can be observed at the open atmosphere outlet. If the outlet is not visible and there is a valve in the exhaust pipe, this can be shut and the indicator cock on the opposite end of the cylinder opened, thereby diverting the steam which leaks and causing it to appear at the indicator cock. In a condensing engine where no atmospheric exhaust is provided, and where there is no opening that can be made in the exhaust pipe between the engine and the condenser, some idea can be obtained in regard to the amount of leakage by observing how rapidly the condenser is heated. It is well to make these tests with the piston in different positions, so as to cover the whole range of the length of the stroke.

5f. Another method of testing for the degree of leakage is called the "time method." Instead of observing the steam that actually blows past the valves or piston to be tested, they are subjected to full steam pressure, and when the parts are thoroughly heated, the throttle valve is shut and the length of time which is required for the pressure to disappear is observed. In testing the piston and exhaust valves, the flywheel is blocked as before, and, preferably, an indicator is attached, and lines drawn on a blank card at intervals of, say, one-quarter of a minute after the valve is shut, thereby making a record of the fall of the pressure. In a tight engine the fall of the pressure is slow, whereas in a leaky engine it is sometimes very rapid. The relative condition of the engine under test as compared with a tight engine must be judged by the observer, who must, of course, have had experience in tests of this kind on engines in various conditions. The leakage of a piston may be determined by removing the cylinder head, after first blocking the engine, and observing what blows through the open end with the pressure of steam behind it. The advantage of the time method is that it saves the labor and time required in removing the cylinder head and replacing it, which, in the case of large engines, is considerable.

5g. Leakage tests of single-valve engines cannot be made as satisfactorily as those of the four-valve type. The best that can be done as regards the valve is to place it at or near the center of its travel, covering both ports, and then make the test under full pressure. The valve and piston can be tested as a whole by blocking the flywheel and opening the throttle valve in the same way as in the other engines.

5h. In testing compound engines for the degree of leakage the work is somewhat simplified, as compared with a simple engine. For example, leakage of the high-pressure cylinder can be revealed by opening the indicator cock on the proper end of the low-pressure cylinder, the steam valve of that cylinder being open. The test of leakage of the low-pressure exhaust valve and piston when the time method is used may be based on the indication of the receiver gage, instead of using an indicator. In that case the fall of the pressure due to leakage is read directly from the gage.

5i. In four-valve engines the degree of leakage of the piston with the engine in operation can be observed by removing the cylinder head, disconnecting the steam and exhaust valves at the head end, and setting the engine to work with steam admitted at the crank end only.

5j. Referring to leakages that vitally affect the accuracy of a test, it is not always necessary to blank off a connecting pipe to make sure that there is no leakage through it. If satisfactory assurance can be had that there is no chance for leakage, this is sufficient. For example, where a straight-way valve is used for cutting off a connecting pipe, and this valve has double seats with a hole in the bottom between them, this being provided with a plug or pet cock, assurance of the tightness of the valve when closed can be had by removing the plug or opening the cock. Likewise, if there is an open drip pipe attached to an unused or empty section of pipe beyond the valve, the fact that no water escapes here is sufficient evidence of the tightness of the valve. The main thing is to have positive evidence in regard to the tightness of the connections, such as may be obtained by the means suggested above. But where no positive evidence can be obtained, or where the leakage that occurs cannot be measured, it is of the utmost importance that the connections should be broken and blanked off. Leakage of relief valves which are not tight, drips from traps, separators, etc., and leakage of tubes in the feedwater heater must all be guarded against or measured and allowed for. It is well as an additional precaution to test the tightness of the feedwater pipes and apparatus concerned in the measurement of the water by shutting the feed valves at the boilers, making sure that they are tight, and turning steam on to the feed pump. If there is no leak the pump can run only as fast as is permitted by its own slippage. Leakage will be revealed by disappearance of water from the supply tank. A gage should be placed on the pump discharge to guard against undue or dangerous pressure.

5k. To determine the leakage of steam and water from boiler, steam pipes, etc., up to engine throttle valve, the water-glass method may be satisfactorily employed. This consists of shutting off all the feed valves (which must be known to be tight) including the main feed valve, thereby stopping absolutely the entrance or exit of water through the feed pipes to or from the boiler; then maintaining the steam pressure in boiler and steam lines (by means of a very slow fire) up to a fixed point, which is approximately that of the working pressure, and observing the rate at which the water falls in the gage glasses. It is well, in this test, as in other work of this character, to make observations every ten minutes, and to continue them for such length of time that the differences between successive readings become constant. In many cases the conditions will have become constant at the expiration of fifteen minutes from the time of shutting the valves. In boilers with much brickwork, especially if run at a high rate, it will be several hours before pressure conditions become constant and safety valves stop popping. Thereafter the fall of the water level due to leakage of steam and water becomes approximately constant. It is usually sufficient, after this time, to continue the test for two hours, thereby obtaining a number of half-hourly periods. When this test is finished, the quantity of leakage is ascertained by calculating the volume of water which has disappeared, using the area at the water level and the depth shown on the glass, and multiplying by the weight of one cubic foot of water at the temperature observed. The water columns should not be blown down during the time a water-glass test is going on, nor for a period of at least one hour before it begins. If there is opportunity for condensation to occur and collect in the steam pipe during the leakage test, the quantity should be determined as closely as possible and properly allowed for.

**6. *Steam Consumption.* The steam consumption of an engine equipped with a surface condenser should be determined by measuring the condensate from the condenser, assurance being obtained that all the steam entering the cylinders passes into the condenser. If the condenser leaks, the defects causing the leaks should be remedied or suitable corrections should be made. The water of condensation from jackets and heaters, if not included in the condensate, should be weighed separately and added thereto. If a surface condenser is not available, the steam consumption should be determined by feedwater tests, which require the measurement of the various supplies of water fed to the boiler, of the water wasted by separators and drips on the main steam line, of the steam used for other purposes than the main engine cylinders, and of water and steam which escape by leakage from the boiler and piping. All of these last quantities must be determined and be deducted from the total measured feedwater supplied to the boiler. The heat consumption is determined from the steam consumption as pointed out in Par. 12.**

6a. In making an engine test where the steam consumption is determined from the amount of water discharged from a surface condenser, leakage of the piston rods and valve rods should be guarded against; for if this is excessive, the test is of little use, as the leakage consists partly of steam that has already done work in the cylinder and partly of water condensed from the steam in contact with the cylinder. Leakage of the condenser itself may be determined by operating the condenser under vacuum when all steam from the engine is shut off, and observing the rate at which the water, if any, is discharged by the condensate pump. When salt water is used for circulating water, leakage may be determined by testing the condensate with silver nitrate or by some other suitable method such as the conductivity bridge or the Dionic tester. If a few drops of solution of silver nitrate added to a sample of condensate produce a white precipitate, the presence of salt water is indicated.

6b. When no other method is available, the steam consumption may be determined approximately by the use of a steam meter calibrated under the conditions of use.

6c. The steam consumed by independently driven auxiliaries which are required for the operation of the engines should not be included in the total steam from which the steam consumption is calculated. These should be supplied from a separate boiler, if possible, if the steam consumption is determined by the measurement of feed water.

6d The steam consumption of auxiliaries may be determined approximately by the water-glass test, as described in Par. 5k.

### Operating Conditions

**7. The operating conditions conforming to the object in view should prevail throughout the trial, as pointed out in Par. 19, of the "General Instructions."**

### Starting and Stopping

**8. The engine and appurtenances should first be thoroughly heated and run under the prescribed conditions until uniformity is secured. If the period to be covered by the test includes the time employed in warming up a cold engine, as in the practice of many industrial plants, the preliminary heating should be omitted, and the conditions should all conform to the usual operations.**

8a. When a surface condenser is used, the test should start by commencing to weigh or measure the condensate and any other quantities of steam consumption involved, at the same time beginning the regular observations and other necessary test work. At the end of the allotted time the test is stopped by discontinuing

the measurements and observations. When feedwater measurements are employed, the test should be started by carefully observing the steam pressure and water level in the boiler, and the level in the feed tank, if measuring tanks are used, at the same time beginning the water measurements and taking up the regular work of the test. At the end of the prescribed time, the water levels and steam pressure should be brought as near as practicable to the same points as at the start, and the observations discontinued. If there are differences in the water levels or pressure, proper corrections must be applied to the water measurements.

8b. When feedwater measurements are employed care should be taken in cases where the activity of combustion affects the height of water, that the same conditions of fire and draft are secured at the end as at the beginning. Care should also be observed to note the average height of water in the glass when the water line fluctuates.

### Duration

9. When surface-condenser measurement is employed and the load is substantially constant, the test should be continued for such time as may be necessary to obtain a number (not less than three) of successive half-hourly records during which the results are reasonably uniform. When the steam consumption is determined by measuring the feedwater supplied to the boiler, the run should be as long as the operating conditions permit. For accurate results the duration of such a test should be at least five hours.

9a. When the conditions determined upon are such that the load varies widely at different times, the duration should be such as to cover at least the entire period of variation.

### Records

10. The general data should be recorded as pointed out in Pars. 20 to 30 of the "General Instructions." Instruments should be read and indicator cards taken from each end of each cylinder at least quarter-hourly when the conditions are uniform and oftener when there is much variation. If there are wide fluctuations in readings they should be shown by recording instruments. Each indicator card should be marked with the number, date, time, scale of spring and end of cylinder, and on one card of each set the readings of the steam gages should be recorded. The log should contain the record of the readings of steam and vacuum gages, thermometers, calorimeters, speed indicator, load-measuring devices, and all other instruments, and these readings should be obtained at practically the same time the indicator cards are taken. The areas, lengths, mean effective pressures, and cut-offs shown by the indicator cards, should also be entered in the log. If complete test data are desired, representative steam-pipe diagrams should be taken with an indicator applied near the throttle-valve gage and operated by connection to the reducing motion of the cylinder indicators.

10b. A set of specimen indicator diagrams should be carefully selected from the whole number taken, and these should be embodied in the record. The specimen cards selected should be such as to show the average conditions of pressure and cut-off. If steam-pipe diagrams are obtained, specimens of these should also be placed in the record.

### Calculation of Results

11. *Steam Consumption.* Whether the engine is supplied with wet, dry and saturated, or superheated steam, the actual steam consumption is stated in the report of the test. When the engine is supplied with wet steam, the quantity of dry and saturated steam comprised in the wet steam is found by deducting from the total weight of steam as measured the moisture as shown by a calorimeter near the throttle. Superheated steam requires no correction. The "equivalent steam" consumed corresponding to any desired or specified set of conditions as to moisture, superheat, pressure, and vacuum which differ from the conditions of the test—such, for example, as those required by a contract guarantee or acceptance test—should be determined in the manner previously agreed upon by the interested parties in accordance with Par. 3 of the "General Instructions." (See Code on Definitions and Values, Par. 93.)

11a. In view of the fact that "dry saturated steam" is practically unobtainable commercially and that the presence of moisture is detrimental to the economy of the engine to a greater degree than the amount present in the steam would indicate, arbitrary corrections (referred to in Par. 11 above) for correcting the actual steam consumption for quality are to be used in arriving at a value of "Equivalent Steam."

12. *Heat Consumption.* The number of heat units consumed by an engine per hour is found by multiplying the consumption, as measured in pounds of steam per hour, by the difference between the total heat in one pound of steam at the average pressure and of average quality found in the steam pipe near the throttle and the heat in one pound of water at the temperature of saturated steam at the average pressure existing in the exhaust pipe near the cylinder.

13. *Indicated Horsepower.* The indicated horsepower for each end of the cylinder is found by using the formula

$$I.hp. = \frac{PLAN}{33{,}000}$$

where $P$ represents the mean effective pressure in pounds per square inch $L$ the length of the stroke in feet, $A$ the area in square inches of the piston less the area of the piston rod, if any, and $N$ the number of revolutions per minute. The total horsepower of the cylinder is the sum of the horsepower developed in the two ends.

13a. The mean effective pressure should be found by dividing the area of the diagram in square inches as determined with a correct planimeter, by the length of the diagram in inches, and multiplying the quotient by the average corrected scale of the indicator spring. If a planimeter is not available, the approximate mean effective pressure may be determined by finding the average height of the diagram in inches as obtained by averaging a suitable number of ordinates, at least ten, measured between the lines of the forward and return strokes, and then multplying this average by the scale of the spring.

14. *Brake Horsepower.* The brake horsepower is found by multiplying the net pressure or force $W$ in pounds on the brake arm—that is, the gross pressure minus the weight when the brake is entirely free from the pulley—by the circumference of the circle whose radius is the horizontal distance $L$ in feet between the center of the shaft and the bearing point at the end of the brake arm, and by $N$ the number of revolutions of the brake shaft per minute, and dividing the final product by 33,000.

$$B.hp. = \frac{2\pi LWN}{33{,}000}$$

See code on Instruments and Apparatus for descriptions and methods of applying brakes.

15. *Electrical Horsepower.* The electrical horsepower of a generator is found by dividing the output at the terminals expressed in kilowatts by the constant 0.7457. In the case of an alternating-current generator the quantity of output determined, whether expressed in electrical horsepower or kilowatts, should be the net output. When the power for excitation or ventilation is taken directly from the engine shaft, the net output is that indicated at the a.c. generator terminals. When this power is taken from the a.c. generator through a motor or from some outside source, the net output is found by deducting the current furnished as excitation from that indicated at the terminals.

16. *Thermal Efficiency.* The proportion of the total heat consumption which is converted into work is called the "thermal efficiency," and is found by dividing 2,547 (B.t.u. equivalent to 1 hp.-hr.) by the number of heat units actually consumed per hp.-hr. (Par. 12). The quotient is multiplied by 100 to express the thermal efficiency in per cent. The formula is

$$\text{Thermal Efficiency} = \frac{2547}{w\,(H_1 - q_2)}$$

where

$w$ = pounds of steam as supplied per i.hp-hr.;
$H_1$ = Total heat above 32 deg. per pound of steam at the initial conditions prevailing before throttle valve;
$q_2$ = Heat of liquid above 32 deg. in one pound of water at the temperature of saturated steam at exhaust pressure.

17. *Engine Efficiency.* The engine efficiency is the ratio obtained by dividing the heat equivalent of the actual work done by the heat available for an ideal engine. The accepted standard for the ideal steam engine is the Rankine cycle (Code on Definitions and Values, Par. 89). The engine efficiency is obtained by the following equation:

$$\text{Engine Efficiency (referred to i.hp.)} = \frac{2547}{w\,(H_1 - H_2)}$$

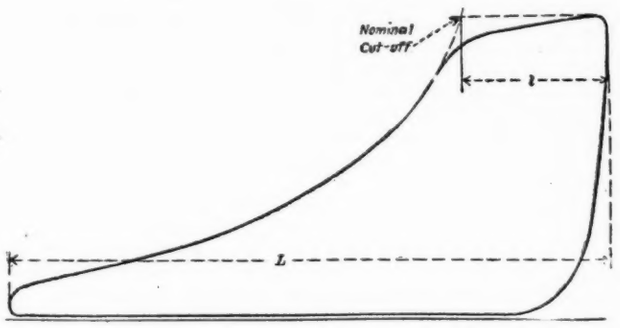
where

$w$ = Pounds of steam per i.hp-hr.;
$H_1$ = Total heat above 32 deg. per pound of steam at the initial conditions prevailing before the throttle valve;
$H_2$ = Total heat above 32 deg. per pound of steam after adiabatic expansion from initial conditions to the final pressure.

$H_1$ and $H_2$ can be found from any Total Heat-Entropy diagram. $(H_1—H_2)$ is the heat available for work.

18. *Nominal Cutoff.* The nominal cutoff can be found in the following manner from an indicator card: Through the point of maximum pressure during admission a line is drawn parallel to the atmosphere. Then, through a point

near the top of the expansion line where the cutoff is complete, a hyperbolic curve is drawn. The intersection of these two lines is the point of nominal cutoff, and the proportion of cutoff is found by dividing the length measured on the diagram up to this point by the total length, as shown in Fig. 1.




Note.—The method of calculating the steam accounted for by the indicator card has been omitted for the following reasons:
(a) It is not essential to a performance test of an engine;
(b) As this method does not even approximate the actual steam consumption of an engine, it is liable to be misleading unless thoroughly understood.

19. *Throttle Pressure.* The throttle pressure, or the average pressure in the steam pipe just before the throttle, is that shown by a corrected steam gage attached at the desired point, the fluctuations of which are reduced so far as may be by choking the gage cock. When extreme accuracy is desired or when the fluctuations are large the average pressure may be found by working up the steam-pipe diagram taken at or near the same point and finding the mean pressure for the entire stroke, during the periods of admission. The superheat or quality of the steam supplied should be measured in the steam supply pipe before the throttle valve.

19a. In the case of guarantee tests of capacity, if so agreed upon, the throttle pressure may be taken as the minimum pressure shown on an indicator diagram taken from the steam pipe near the throttle.

## Data and Results

20. The data and results should be reported in accordance with the form (Table 1) given herewith, adding lines for data not provided for, or omitting those not required, as may conform to the object in view. If the principal data and results pertaining to steam consumption only are desired, the subjoined abbreviated table (Table I) may be used. Unless otherwise indicated, the items should be the averages of all observations.

See Note 1 of Table 1 for references to engines driving electric generators and other machinery.

TABLE I. DATA AND RESULTS OF RECIPROCATING STEAM-ENGINE TEST

*(A.S.M.E. Code of 1920; Long Test)*

General Information

(1) Date of test.....
(2) Location .....
(3) Owner .....
(4) Builder .....
(5) Test conducted by.....
(6) Object of test.....

Description, Dimensions, etc.

(7) Type of engine (simple or multiple expansion).....
(8) Class of service (mill, marine, electric, etc.).....
(9) Auxiliaries (steam or electric drive).....
(10) Type and make of condenser equipment.....
(11) Rated capacity of condenser equipment.....
(12) Type of oil pump, jacket pump, and reheater pump (direct or independently driven).....
(13) Rated power of engine.....
(14) Kind of valves.....
(15) Type of governor.....

| | First | Second | Third |
|---|---|---|---|
| (16) Diameter of cylinders | in. | in. | in. |
| (a) Diameter of piston and tail rods | in. | in. | in. |
| (17) Stroke of pistons | in. | in. | in. |
| (18) Clearance volume in per cent of piston displacement | | | |
| (a) Clearance head end | in. | in. | in. |
| (b) " crank end | in. | in. | in. |
| (c) " average | in. | in. | in. |

(19) Head end hp. constant (stroke × net piston area ÷ 33,000).
(20) Crank end hp. constant (stroke × net piston area ÷ 3,300).
(21) Cylinder ratio (based on net piston displacement), 1 to.....
(22) Area of interior seam surface.....sq.ft.
(23) Area of jacketed surfaces.....sq.ft.
(24) Capacity of generator or other apparatus consuming power of engine.....hp. or kw.

Test Data and Results

(25) Duration of test .....hr.

*Average pressures*

(26) Barometric pressure..... in. of mercury....lb. per sq.in.
(27) Pressure in steam pipe near throttle by gage....lb. per sq.in.
(a) Corresponding absolute pressure.....lb. per sq.in.
(b) Minimum pressure above atmosphere, steam-pipe diagram near throttle.....lb. per sq.in.
(c) Minimum pressure above atmosphere, steam-pipe diagram near throttle.....lb. per sq.in.
(28) Pressure in 1st receiver, by gage.....lb. per sq.in.
Corresponding absolute pressure .....lb. per sq in.
(29) Pressure in 2d receiver, by gage.....lb. per sq.in.
Corresponding absolute pressure .....lb. per sq in.
(30) Pressure or vacuum in exhaust pipe near engine by mercury column .....in of mercury
(a) Corresponding absolute pressure.....lb. per sq.in.
(31) Pressure in jackets and reheaters.....lb. per sq.in.

*Temperatures*

(32) Engine-room temperature .....deg. fahr.
(33) Temperature of steam near throttle.....deg. fahr.
(34) Temperature of saturated steam at throttle pressure .....deg. fahr.
(35) Temperature of steam if superheated:
(a) Entering 1st receiver.....deg. fahr.
(b) Leaving 1st receiver.....deg. fahr.
(36) Temperature of steam if superheated:
(a) Entering 2d receiver .....deg. fahr.
(b) Leaving 2d receiver.....deg. fahr.
(37) Temperature of saturated steam corresponding to pressure in exhaust pipe near engine.....deg. fahr.
(38) Temperature of steam in exhaust pipe, as observed.deg. fahr.

*Quality of Steam at Throttle*

(39) Number of degrees of superheat.....deg. fahr.
(40) Percentage of moisture in steam.....per cent

*Total Quantities*

(41) Total steam consumed by engine, as measured (see Par. 6) .....lb.
(42) Total dry and saturated steam or superheated steam consumed (Par. 11).....lb.
(43) Correction factor conforming to conditions agreed upon (See Pars. 11 and 11a).....
(44) Equivalent total steam consumed, conforming to conditions agreed upon (Item 41 × Item 43).....lb.

*Hourly Quantities*

(45) Steam consumed per hour as measured (Item 41 ÷ Item 25) .....lb.
(46) Dry and saturated steam or superheated steam consumed per hour (Item 42 ÷ Item 25).....lb.
(47) Equivalent steam consumed per hour conforming to conditions agreed upon (Item 44 ÷ Item 25).....lb.

*Heat Consumption*

(48) Total heat above water at 32 deg. fahr. per lb. of steam at throttle .....B.t.u.
(a) Heat of liquid at temperature of steam at exhaust pressure .....B.t.u.
(b) Heat supplied per pound of steam.....B.t.u.
(49) Heat consumed per hour (See Par. 12).....B.t.u.
(50) Heat available for work per lb. of steam, from adiabatic expansion between initial conditions and final pressure according to Rankine cycle (See Par. 17)..B.t.u.

*Indicator Diagrams* 1st Cyl. 2d Cyl. 3d Cyl.

(51) Nominal cut-off.....per cent
(52) Mean effective pressure (avgr.).....lb. per sq.in.
(53) Maximum pressure above atmosphere.....lb. per sq.in.
(54) Absolute back pressure at lowest point.....lb. per sq.in.

*Speed*

(55) Revolutions per minute.....r.p.m.
(a) Variation of speed between no load and full load .....per cent
(b) Momentary fluctuation of speed on suddenly changing from full load to half load.....per cent
(56) Piston speed .....ft. p.m.

*Power*

(57) Indicated horsepower developed by whole engine.....i.hp.
(58) 1st cylinder, crank end.....i.hp.
head end .....i.hp.
(59) 2d cylinder, crank end.....i.hp.
head end .....i.hp.
(60) 3d cylinder, crank end.....i.hp.
head end .....i.hp.
(61) Brake horsepower developed by whole engine.....b.hp.
(62) Friction of engine Item 57 — Item 61.....hp.
(63) Percentage of friction (Item 62 ÷ Item 57) × 100..per cent
(64) Indicated horsepower with no load at normal speed.....i.hp.
(65) Mechanical efficiency (Item 61 ÷ Item 57) × 100...per cent

*Economy Results*

(66) Steam consumed per i.hp.-hr. as measured (Item 45 ÷ Item 57) .....lb.
(67) Dry saturated or superheated steam consumed per i.hp.-hr. (Item 46 ÷ Item 57) .....lb.
(68) Equivalent steam consumed per i.hp.-hr. conforming to conditions agreed upon (Item 47 ÷ Item 57).....lb.
(69) Steam consumed per b.hp.-hr. as measured (Item 45 ÷ Item 61) .....lb.
(70) Dry and saturated steam or superheated steam consumed per b.hp.-hr. (Item 46 ÷ Item 61).....lb.
(71) Equivalent steam consumed per b.hp.-hr. conforming to conditions agreed upon (Item 47 ÷ Item 61).....lb.
(72) Heat consumed per i.hp.-hr. (Item 49 ÷ Item 57).....B.t.u.
(73) Heat available according to Rankine cycle per i.hp.-hr. (Item 50 × Item 66).....B.t.u.
(74) Heat consumed per b.hp.-hr. (Item 49 ÷ Item 61)....B.t.u.
(75) Heat available according to Rankine cycle per b.hp.-hr. (Item 50 × Item 70) .....B.t.u.

TABLE I. CONCLUDED

*Efficiency Results*

(76) Thermal efficiency referred to i.hp. (2547 ÷ Item 73) × 100 ..... per cent
(77) Thermal efficiency referred to b.hp. (2547 ÷ Item 74) × 100 ..... per cent
(78) Engine efficiency (referred to Rankine cycle) based on i.hp. (2547 ÷ Item 73) × 100 ..... per cent
(79) Engine efficiency (referred to Rankine cycle) based on b.hp. (2547 ÷ Item 75) × 100 ..... per cent

*Specimen Diagrams*

(80) Sample diagram from each cylinder .....
(81) Sample steam-pipe diagram .....

NOTE 1: When the engine drives an electric generator the following additional data and results applicable especially to a.c. generators should be entered in the table.

*Electrical Data*

(82) Average volts each phase ..... volts
(83) Average amperes each phase ..... amp.
(84) Power factor ..... per cent
(85) Total output in kilowatts ..... kw.
(86) Net output in kilowatts (See Par. 15) ..... kw.
(*a*) Field volts .....
(*b*) Field amperes .....

*Power and Economy*

(87) Electrical horsepower developed (Item 86 ÷ 0.7457) .....
(88) Steam consumed per net kw.-hr. (Item 45 ÷ Item 86) ... lb.
(89) Dry and saturated steam or superheated steam consumed per net kw.-hr. (Item 46 ÷ Item 86) ..... lb.
(90) Equivalent steam consumed per net kw.-hr. (Item 47 ÷ Item 86) ..... lb.
(91) Heat consumed per net kw.-hr. (Item 49 ÷ Item 86) .. B.t.u.

NOTE 2: When testing a marine engine having a shaft dynamometer, the form should include the data obtained from this instrument, in which case the brake horsepower becomes the shaft horsepower.

TABLE II. DATA AND RESULTS OF RECIPROCATING STEAM-ENGINE TEST

(*Short Test*)

(1) Dimensions of cylinders .....
(*a*) Diameter of piston and tail rods .....
(2) Date .....
(3) Duration ..... hr.
(4) Pressure in steam pipe near throttle by gage .... lb. per sq.in.
(5) Pressure in receivers by gage ..... lb. per sq.in.
(6) Vacuum in condenser ..... in. mercury
(7) Percentage of moisture in steam near throttle or number of degrees of superheat ..... per cent or deg. fahr.
(8) Total steam consumed per hour ..... lb.
(9) Total dry and saturated steam of superheated steam consumed per hour ..... lb.
(10) Equivalent steam consumed conforming to conditions agreed upon per hour ..... lb.
(11) Average mean effective pressure in each cylinder . lb. per sq.in
(12) Revolutions per minute ..... r.p.m
(13) Indicated horsepower developed ..... i.hp.
(14) Steam actually consumed per i.hp.-hr. ..... lb.
(15) Dry and saturated steam or superheated steam consumed per i.hp.-hr. ..... lb.
(16) Equivalent steam consumer per i.hp.-hr. conforming to conditions agreed upon ..... lb.
(17) Engine efficiency (referred to Rankine cycle based on i.hp.) ..... per cent

## Interconnection of Hydro-Electric Energy in the Northwest

Interconnection of all hydro-electric energy in the State of Washington, to link up with the energy of Oregon and California and to afford a connected power chain all along the Pacific Coast, is a feasible project as far as this state is concerned, declare Seattle electric experts in connection with the proposed project from British Columbia to Mexico.

This vast linking of hydro-electric energy, establishing a superpower transmission project, is one of the big future electrical developments to come with the industrial and population expansion of state rural and urban districts, admitted local power authorities. While this proposal is under consideration here, a committee representing the American Association of Engineers, Oregon Chapter, has undertaken a survey in the Oregon district of a connected superpower system from Canada to the Mexican line.

"Like further railroad electrification, this superpower plan is a project of the future, to be carried out when economic conditions warrant," declared William H. McGrath, vice president of the Puget Sound Power and Light Co., recently. "There is a superpower system now operating in this state on a smaller scale, and only the construction of approximately fifty miles of transmission lines is needed to have all the state linked up from Spokane to Seattle and from the British Columbia line to a point near Portland." Linking up with Portland would mean a superpower transmission project connecting Washington, Oregon and British Columbia and as far inland as Spokane, he said.

As a result of the power lines erected by the Puget Sound Power and Light Co. for the electrification of the western end of the Chicago, Milwaukee & St. Paul Ry., the Cities of Seattle and Spokane are now linked, with electricity being sent by the Seattle company to the Washington Water Power Co., of Spokane, when needed and vice versa. This connection, however, would not have been possible had it not been for railroad electrification.

Only thirty miles of transmission lines would be necessary to fill the gap between Everett and Mount Vernon, thereby connecting the northern and southern divisions of the Seattle company. Power for the northern division is furnished by the Nooksack water-power plant and a steam plant at Bellingham, while power is also furnished the Skagit district from lines of a Canadian company crossing the international boundary.

The southern division, which is separated from the northern part of the state by the thirty-mile gap, is a small superpower system in itself, with water-power plants at Snoqualmie, White River and Electron, including steam plants at Tacoma, Seattle and Everett, all connected with Spokane over the Milwaukee electrification lines.

The other gap, which separates Washington and Oregon, is but twenty miles long—between Olympia, reached by the Seattle plant, and Tenino, where a private company operates a smaller power line, operating it south to a point near Portland. The filling in of these two gaps with transmission lines would automatically link up all of this state practically to Portland; or the electrification of the Northern Pacific line between Seattle and Portland would also effect this chain of power energy, it was pointed out.

"The first step," said Mr. McGrath, "would be the joining of the northern and southern divisions. Then a high-power line could be built from Electron to Portland as the next step. This latter line, however, would aggregate a cost of somewhere around $5,000,000."

While entirely feasible, this scheme is for the future, awaiting a sufficient industrial and population increase, emphasized Mr. McGrath.

### STEPS TAKEN BY PORTLAND CHAPTER, A. A. E.

First steps toward the establishment of a gigantic power system which would link up all hydro-electric energy on the Pacific Coast, from British Columbia to Mexico, have just been taken by the executive committee of the Portland chapter of the American Association of Engineers of a committee of seven to study the feasibility of the plan.

The committee is composed of P. A. Cupper, state engineer; O. Laurgaard, city engineer; J. C. Stevens, F. D. Weber, D. C. Henry, Fred Hesse, W. H. Cullers, P. Libenbaum, F. F. Henshaw, E. R. Cunningham, R. W. Barnes, Thomas Pumphrey, R. H. Dearborn, W. S. Turner and L. T. Merwin. This committee will select a subcommittee of seven, who will survey the potential power possibilities and formulate a definite plan for co-ordinated development of existing plants.

The Chamber of Commerce is backing the engineers in their investigation and will assist in collecting data.

The object of the plan is eventually to establish what is technically known as a superpower transmission project, leading features of which are conservation of energy, adequate supply at all times and economical operation of establishments supplied. It is planned to utilize such existing plants and equipment as are not in positions of economic disadvantage.

Such a system is now in use between Boston and Baltimore.

## Takes Over Railway Load

Operation of the Jersey City power plant of the Hudson & Manhattan Railroad Co. (familiarly known to New Yorkers as the Hudson Tubes) has been taken over by the New York Edison Co., which has tied it in with its own system. This step is in line with a tendency in many electric railway circles to divorce their power-plant problems from those of transportation; and on the other hand, it increases the diversity of the central-station load.

## Boiler Explosion at Dunwoody, Ga.

As a result of a boiler explosion at Dunwoody, Ga., recently, three men who were not connected with its operation were killed and the boiler room demolished. The boiler was installed twenty years ago, and the owner does not know whether it was new or second-hand when purchased at that time. It was 48 in. in diameter by 12 ft. in length, of single-riveted lap-joint construction, made of ¼-in. charcoal-iron plate and contained fifty 3-in. tubes. But five tubes remained in the head of one of the sections that was found about a quarter of a mile from the boiler house. The boiler is said to have been equipped with a spring-loaded safety valve, 2 in. in diameter and set to blow at 100 lb. pressure. The steam gage, when found, registered 80 lb., and, according to the fireman's statement, this pressure was carried by the boiler shortly before the explosion.

The boiler was of two courses, and each had a single-riveted patch on the bottom. The shell parted at about the middle in a girthwise direction and also tore open away from the seam, rolling or bending back toward the rear head in one of the exploded sections. None of the seams gave way, each of the separations were away from the seams except at the front head where the plate tore away along with the line of rivets around the head seam. Various parts of the shell where it had been bruised showed laminations and were very brittle. Wherever the shell has been dented in or out, an embrasure showed breaking of the shell as with cast iron.

There is no explanation as to the cause of the explosion other than that the pressure was in excess of what the boiler strength could carry. Had it been under inspection, it probably would have been condemned long ago.

## An Oil-Country Boiler Explosion

At 12:30 a.m. on November 16 last, an oil-burning, locomotive-type boiler exploded near Haydenville, Ohio, causing the death of one man and the serious injury of another. As under present regulations oil-burning boilers

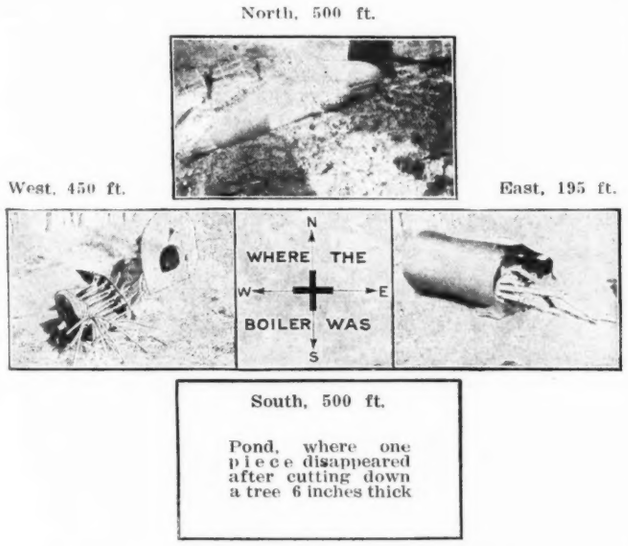



FIG. 1. PIECES OF THE BOILER WERE HURLED TO THE LOCATIONS SHOWN

are exempt from the boiler regulations of the State of Ohio, it had never been inspected. It was 12½ ft. long, 40 and 48 in. in diameter, with 44 tubes 3 in. in diameter and 8 ft. long. Tube sheet and head were ⅞ in. thick.

The report of the inspectors shows that this boiler would, owing to its structure and the condition of the staybolts, have been allowed only 29 lb. pressure in conformity with the A. S. M. E. Code, but according to the best information obtainable was operating at about 110 lb. when the explosion occurred. The remarkable force of the explosion is indicated by the distance to which large pieces of the boiler were thrown, as noted in connection with the illustrations.

As shown in Fig. 2 the pop safety valve was provided with a stop cock, which is of interest in connection with a rule of the A. S. M. E. Code which reads as follows: "No

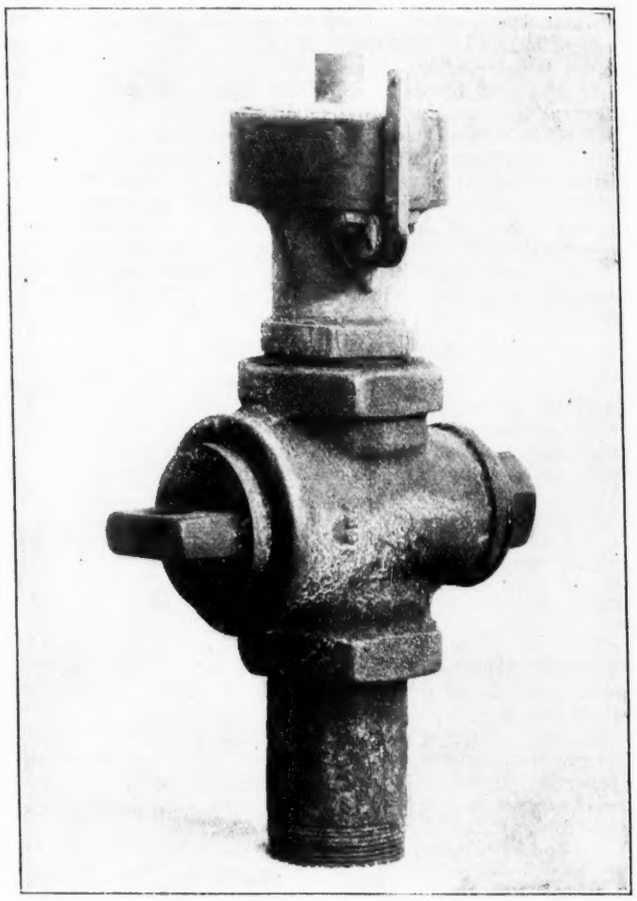


FIG. 2. A FATAL COMBINATION

valve of any description shall be placed between the safety valve and the boiler," etc. The observance of this one simple rule would have prevented the loss of life and destruction of property involved in this accident, the immediate cause of which was the failure of the staybolts in outside wrapper sheets which had in many places corroded so as to be less than ¼ in. thick.

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According to *Commerce Monthly* for January, powdered coal was first put to practical use about 1895 in the cement industry. Cement mills were equipped with the machinery necessary for pulverizing cement rock or clinker, and so the pulverizing of coal was a natural and easy experiment in the effort to reduce the cost of fuel used in such plants. Progress in the use of powdered coal remained practically at a standstill for about fifteen years, but the new type of fuel has become increasingly popular within the last decade. It is estimated that between ten and twelve million tons of it was used in the United States in 1919, of which six million tons was consumed in the manufacture of portland cement; about 250,000 tons was burned in power plants. One of the chief advantages of powdered coal, as has been shown by recent experiments, is that low-grade fuels such as anthracite culm, peat and lignite, may be successfully utilized.

## Marine Exposition Coming to New York City

The National Marine Exposition, which is to be held at Grand Central Palace, New York City, Jan. 24-29, should be of considerable interest to *Power* readers in spite of the fact that it is a marine show. The large number of companies that have arranged for exhibition space, many of which are leaders in their field, and the nature of some of the exhibits as announced, indicate that one who is interested in the generation and transmission of power will be able to find much of value at the exposition.

One exhibit, for instance, which is being prepared by the General Electric Co., will include a complete turbine rotor and other turbine parts, a model showing the electric propulsion machinery of the S.S. "Eclipse" (the first electrically driven American cargo vessel, described in *Power* for Nov. 2, 1920,) and auxiliary apparatus, such as motors and pumps. Much of the machinery will be in actual operation.

A number of exhibitors will show welding outfits, hoists, cranes, boilers and other apparatus that should interest landlappers as well as mariners.

## Steam Formulas

Prof. G. A. Goodenough has submitted a written discussion upon the paper entitled "Steam Formulas," presented by Professor Heck before the American Society of Mechanical Engineers, as reported by *Power* in its December 21, 1920, issue, the opening paragraph of which is as follows:

Professor Heck's paper is the most comprehensive treatment of the properties of steam that has yet been presented to the Society. No one who has not been through the process can appreciate the enormous labor involved in building up such a formulation as is here presented, and Professor Heck has justly earned the gratitude of the mechanical engineers for his keen analysis of a difficult problem.

After a vigorous defense of his methods, as criticised by Professor Heck in the latter part of his paper, Professor Goodenough sums up with the following over-all comparison of his own (G) and Professor Heck's (H) tables:

1. For the range covered, 32 deg. to about 560 deg. F., the two formulations give almost identical values for all the properties of saturated and superheated steam that are usually tabulated. Above 560 deg. the values run fairly close to about 620 deg.

2. For extrapolation from the highest temperatures for which experiments are available to 620 deg., the formulations are equally good.

3. For the range 620 deg. to the critical temperature, the results differ considerably as different methods of extrapolation were employed. The (H) guess is as good as the (G) guess, but no better.

4. As regards simplicity of the equations employed, the (G) formulation has a distinct advantage.

5. In the matter of accuracy there is probably little choice. In some respect the (H) formulation seems to have a slight advantage; in other places the advantage rests with the (G) equations. Thus there is little doubt that the (G) value of the latent heat at 212 deg. is nearer the truth than the (H) value.

The one outstanding point is that here we have two entirely different formulations built up by different methods, but each representing quite accurately the experimental data. They lead to practically identical values of the various properties. The evident conclusion is that we are converging rapidly to final results.

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The American Society of Mechanical Engineers report that J. Parke Channing, one of the vice presidents of American Engineering Council, has received a letter from President-elect Harding, in which Mr. Harding says that he "is very much in favor of bringing together under one department all of the present agencies of public works now scattered around Washington." It is understood that Mr. Harding is favorably disposed toward the efforts of American Engineering Council and other engineering bodies to secure the establishment of a national department of public works.

## Employment Service Bureau to Be Continued

The Engineering Societies Employment Service Bureau is still being maintained in the Engineering Societies Building, 29 West 39th Street, New York City, with Walter V. Brown in charge. As it was a part of Engineering Council, its work has now been transferred to American Engineering Council. Pending the development of a more permanent organization which may direct this very important activity of American Engineering Council, the secretaries of the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers have been requested to act as a committee on management to conduct the Service Bureau until such time as a permanent organization under American Engineering Council can be effected.

The Committee on Procedure of the Executive Board of American Engineering Council, voting to take over the Employment Service, specified that the applicants should be arranged in two groups, preferred and ordinary. The preferred applicants are to be those who are members of constituent societies of American Engineering Council, and the ordinary applicants, all others.

As a means of communicating with the secretaries of the member societies of the Federated American Engineering Societies, a bulletin listing positions open will be regularly issued. The first of these bulletins will be sent very shortly.

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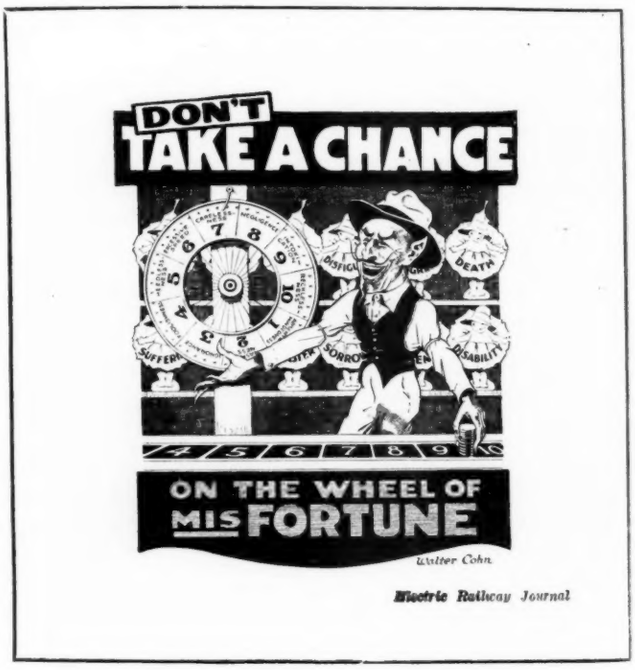
Dr. F. G. Cottrell, formerly director of the Bureau of Mines, gave out a statement recently, describing the work of the bureau in analyzing coals used by the Government and also samples which are collected by field engineers. In this way exact information is being accumulated on the nature of coal from all over the country. Special attention is being given the economic combustion of coal by the small user, as in the home and in the small hand-fired boiler plant. This is a case where thorough research on the part of private individuals or corporations is too costly to be attempted; and so the Bureau of Mines is carrying on the work to the great benefit of the country as a whole. As a plan of fuel conservation which should receive universal support the bureau submits this program: First, investigate the situation and educate the great fuel-burning public to the money and health value of the right fuel, in the right furnace, fired in the right way; and second, aid in the development of preparing new fuels, especially from waste and low-grade fuels, such as lignites.



## New Publications

THE HANDBOOK OF INDUSTRIAL OIL ENGINEERING. By John Rome Battle, M.E. Published by J. B. Lippincott, Philadelphia, Pa. Size, 5 x 7½ in.; 1,065 pages; 395 illustrations.

This volume, which is a revision of the "Lubricating Engineer's Handbook" has been enlarged as to its scope and includes much that, while dealing with the use of petroleum products, does not directly involve lubrication. As separated in sections, the volume fully covers marketing of oil, history of petroleum, petroleum refining, fatty oils, testing of oils, friction, filtering equipment, oil storage, utilization of lubricating oil or industrial practices, lubrication of engines, turbines, motors, etc. This volume gives the busy engineer the essential facts concerning any specific application of lubricating oil and should meet with a ready welcome in engineering circles.

PUMPING BY COMPRESSED AIR. By Edmund M. Ivens, B.E., M.E. Second edition, revised and enlarged. New York, John Wiley & Sons. Cloth bound, 6 x 9 in.; 266 pages; 124 illustrations. Price, $4.

Some thirty pages of text and eighteen illustrations together with a number of formulas and tables have been added to the first edition of this excellent work on the compression, transmission and application of air, with special reference to the lifting and conveying of liquids in connection with the displacement pump and air lift. The added matter consists mainly of operative data, and the work, in its present form, contains practically all the information that is necessary for the intelligent study, design, installation and operation of compressed-air pumping plants. Guided by an extensive practical experience in pumping by compressed air, the author presents the accepted theories; the practical limitations which prevent the theoretial results from being realized in practice; the commercial construction of compressed-air apparatus and material; and illustrative designs that embody the proved economical advantages expressed by the theories as nearly as permissible in practice, with due recognition of interest and depreciation charges.

## Personals

**Charles F. Shultz**, formerly district superintendent of the American Engineering Co., is now chief engineer of the Cromby Plant of the Philadelphia Suburban Gas and Electric Co., at Phoenixville, Pa.

**Samuel W. Dudley** has resigned as chief engineer of the Westinghouse Air Brake Co. to become professor of mechanical engineering at Sheffield Scientific School, Yale University. Mr. Dudley, who was graduated from Yale in 1900, will have charge of experimental engineering under Professor Breckenridge.

**William P. Gregory**, professor of experimental engineering in Tulane University, New Orleans, and irrigation engineer with the United States Department of Agriculture, has been elected vice president of the American Socitiey of Mechanical Engineers to fill the vacancy caused by the death of the late Professor John R. Allen.

**John J. Muir**, who has been connected with the United States Shipping Board Emergency Fleet Corporation, and who has had experience in Calcutta, East India and other foreign countries, has opened offices at 2012 L. C. Smith Building, Seattle, Washington, as a consulting engineer in marine and general engineering work.

**John R. LeValley** has been appointed district manager for the Locomotive Superheater Co., New York, in its newly established Pittsburgh office at 382-388 Union Arcade Bldg. Mr. LeValley was construction and power engineer for Armour & Co.'s Chicago plant, was superintendent of construction and power plants for the Union Stock Yards and Transit Co. and the Produce Terminal Corporation, and served as an officer in the United States Navy for 18 months.

## Society Affairs

**Chicago Section, A. S. M. E.,** will meet at the Hotel Sherman Jan. 24. Fred J. Miller and L. P. Alford will be the speakers, and their topic will be "Labor."

**Philadelphia Section, A. S. M. E.,** will meet at the Engineers' Club on Jan. 25 to hear Julian S. Simsohn, chemical engineer, speak on "Water Treatment for Boilers."

**The National Marine Exposition** will be held at Grand Central Palace, New York City, Jan. 24-29 under the auspices of the National Marine League. Further particulars may be found on another page.

**Atlanta Section, A. S. M. E. and A. S. C. E.,** are to hold a joint meeting in the Carnegie Library on Jan. 25. B. M. Hall, of the Georgia Railway and Power Co., will speak on "Water-Power Development."

**Cincinnati Section, A. S. M. E.,** will meet Jan. 21 to hear an address by President-Elect E. S. Carman. Mr. Carman will discuss "The Engineer and His Opportunity" and "The Federated American Engineering Societies."

**The Engineers' Society of Western Pennsylvania** will hold its annual banquet at the William Penn Hotel, Pittsburgh, on Jan. 24, at 6:45 p.m. Arthur W. Thompson will be toastmaster, and Ellis Parker Butler will be one of the speakers. Reservations should be sent at once.

**Birmingham Section, Association of Iron and Steel Electrical Engineers,** will meet Jan. 27. "Alternating Current in Byproduct Plants" and "Direct Current in Byproduct Plants" will be discussed respectively by W. V. Dunn, chief electrician of the Tennessee Coal, Iron & RR. Co., and by E. R. Winters, chief electrician of the Woodward Iron Co.

**The American Society of Civil Engineers** will hold its 68th annual meeting at New York City on Jan. 19-20. Headquarters will be at the Engineering Societies Building, where the business meeting will be held on the morning of the 19th. In the afternoon and on the following morning excursions will be made to near-by plants, among which will be the Metropolitan Life Insurance Co.'s building.

**The Indiana Engineering Society** will hold its 41st annual meeting at the Claypool Hotel, Indianapolis, on Jan. 27-28. Features of the program for the 27th include a discussion of the Engineer's license law, addresses on "Operating Characteristics of Small Steam-Driven Pumps," "Some Problems in Supplying Electric Power Service to Rural Communities" and "The New 600,000-volt Testing Laboratory at Purdue University."

**The American Society of Heating and Ventilating Engineers** will hold its twenty-seventh annual meeting at New York City and Philadelphia on Jan. 25-28. A business session will be held in New York City at the Engineering Societies Building on Jan. 25, after which the meeting will be adjourned to Philadelphia, where the professional session will be held on Jan. 26-28. Features of the program will include reports from representatives of the Research Bureau at Pitsburgh, reports of important committees, an excursion to the Philadelphia Navy Yard and a banquet. Headquarters will be at the Bellevue-Stratford Hotel.

## Business Items

**Geo. H. Olney & Co.,** 50 Church St., New York City, have added a machine tool division to their regular line of woodworking tools, engines, boilers, stacks, etc.

**The M. J. Dougherty Company,** piping fabricators and contractors, is now fully stablished in new quarters, extending from 24th to 25th Sts. and from Washington Ave. to Ellsworth St., Philadelphia.

**The Yarnall-Waring Co.'s** Chicago representative, H. J. Moyer, who for several years handled the Chicago business of that company and of The Nelson Valve Co., is now giving his whole time to the Yarnall-Waring Co. as district manager, with offices at 58 West Washington St., Chicago.

## COAL PRICES

Current mine quotations, with interesting comparisons, are given in the following tabulation:

| | Nov. 1919* | Aug. 5 1920 | Jan. 6 1921 | Jan. 13 1921 |
|---|---|---|---|---|
| Pittsburgh steam | $2.30 | $10.00 | $2.60 | $2.50 |
| Pitttsburgh screened gas | 2.30 | 12.00 | 3.15 | 3.15 |
| Hocking | 2.50 | 9.00 | 2.50 | 2.50 |
| Franklin, Ill | 2.35 | 6.50 | 3.00 | 3.00 |
| Indiana 4th vein | 2.35 | 7.50 | 2.75 | 2.75 |
| Eastern Ohio, No. 3 | 2.35 | 10.50 | 2.75 | 2.75 |
| Fairmont | 2.50 | 13.50 | 2.40 | 2.20 |
| Kanawha | 2.60 | 14.00 | 2.80 | 2.70 |
| S. E. Kentucky | 3.00 | 10.50 | 2.90 | 2.80 |
| Western Kentucky | 2.35 | 5.25 | 2.60 | 2.60 |
| Clearfield | 2.95 | 12.00 | 3.25 | 3.00 |
| Cambria and Somerset | 2.95 | 13.50 | 4.35 | 3.60 |
| New River | 2.70 | 14.00 | 4.50 | 4.50 |
| Pocahontas | 2.35 | | | |

* Government prices.

## New Construction

### PROPOSED WORK

**Mass., Worcester**—The American Steel & Wire Co., Grove Park, plans to build a 20,000-kw. central power station to replace several power houses in the city.

**Conn., Storrs** (Eagleville P.O.)—The Connecticut Agricultural College, care of Bd. of Trustees, plans to build a 3 story, 40 x 180 ft. science building. About $400,000. Architect not selected.

**N. Y., Albany**—F. C. Huyck & Sons, 3rd Ave., plans to build a boiler house. About $50,000. Griggs & Myers, 110 West 40th St., New York City, Archts. and Engrs.

**N Y., Granville**—The Telescope Cot Bed Co., Inc., 535 West 79th St., New York City, will soon award the contract for a 1 story, 200 x 300 ft. factory and boiler house here. About $100,000. R. G. Cory, 50 Church St., New York City, Archt. and Engr.

**N. Y., New York**—A. Harris, 511 5th Ave., plans to build a 16 story store and office building including a steam heating system at 57th and 58th Sts. Francisco & Jacobus, 511 5th Ave., Archts and Engrs.

**N. Y., New York**—Jallade, Lindsey & Warren, Archts. and Engrs., 129 Lexington Ave., will prepare plans for an 8 story dormitory building including a steam heating system at 29th St. and 1st Ave. About $750,000. Owner's name withheld.

**N. Y., New York**—R. M. Catts, care of Warren & Wetmore, Archts., 10 East 47th St., is having plans prepared for alterations to the Grand Central Palace building to cost about $500,000 and an additional 18 story structure, about $3,000,000. A steam heating system will be installed in same.

**N. Y., New York**—The Bd. Educ. received bids for steam heating apparatus in the Bryant High School, borough of Queens, from E. Ruetzler Co., 404 East 49th St., New York City, $167,467; Gillis & Goeghagan, 537 West Bway., New York City, $171,385; Federal Htg. Co., 300 Madison Ave., New York City, $172,900.

**N. J., Jersey City**—Gershanowitz Bros., Sipp Ave, plan to build a 5 story model apartment house at 630 Bergen Ave. About $450,000.

**N. J., Jersey City**—The Goodman Warehouse Co. had plans prepared for a 6 story warehouse including a steam heating system. About $325,000. Moores & Durford, 38 South Dearborn St., Chicago, Ill., Archts. and Engrs.

**N. J., Princeton**—The Princeton University plans to build a hospital to cost several hundred thousand dollars. J. G. Hibben, Pres.

**N. J. Secaucus**—The Blvd. Comrs. of Hudson Co. Jersey City received bids for installing 2 new generators in the power house here, and making repairs to plant, from Watson-Flagg Engr. Co., New York City, $30,095; C. D. Hunt, 4244 Blvd., West Hoboken, N. J., $55,000; Ajax Electric Co., 56 Baldwin Ave., Jersey City, N. J., $56,700. Noted Aug. 3.

**N. J., Westfield**—A. S. Flagg is having plans prepared for a theater including a steam heating system. About $400,000. Reilly & Hall, 405 Lexington Ave., New York City, Archts.

**N. J., Wharton**—The Borough Council will receive bids until January 31 for water

works improvements including a pumping station, filters, etc. J. Kernick, Clk.

**Pa., Altoona**—W. N. Decker, Secy. of the Bd. Dirs. Altoona School Dist., will receive bids until about March 1 for a 2 story, 100 x 120 ft. power house on 6th Ave. About $200,000. Wood, Hulse, Yates & Co., Inc., Woolworth Bldg., New York City, Archts. Noted Feb. 16.

**Pa., Dormont**—The Bd. Educ. had preliminary plans prepared for a 2 story high school at Snyder St. Cost between $400,000 and $500,000. P. C. Dowler, Magee Bldg., Pittsburgh, Archt.

**Pa., Reading**—The Reading Hospital, Front and Spring Sts., is having plans prepared for a 6 story, 40 x 200 ft. operating addition and power house. About $350,000. F. H. Muhlebberg, Flanders Bldg., Philadelphia, Archt.

**Va., Norfolk**—The Bd. Educ. is having plans prepared for a 4 story, 150 x 310 ft. junior high school, including a steam heating system, at Spottswood Ave. and Washington Park. About $700,000. Calrow, Wrenn & Tazewell, Norfolk, Archts.

**N. C., Reidsville**—The city plans an election soon to vote on $350,000 bonds for a school building. W. C. Northup, Winston-Salem, Archt.

**S. C., Charleston**—The Bureau of Yards and Docks, Navy Dept., Washington, D. C., received bids for boiler plant improvements at the navy yard here, from Carroll Electric Co., 714 12th St., N. W., Washington, D. C., $88,300; Noland Clifford Co., 330 28th St., Newport News, Va., $89,643; Shevlin Engr. Co., 110 West 34th St., New York City, $90,967. Noted Dec. 14.

**O., Cleveland**—The Brotherhood of R.R. Trainmen, A. E. King, Secy., Amer. Trust Bldg., plans to build an 8 story commercial building, including a steam heating system, at West 9th St. and Superior Ave. About $300,000. Architect's name withheld.

**O., Columbus**—The Scottish Rite, Masonic Temple, is preparing sketches for a temple on West Long St. About $600,000.

**O., Middleport**—The Bd. Educ., M. E. Danford, Pres., is having plans prepared for a 2 story high school. About $500,000. T. D. McLaughlin, Lima, Archt.

**O., Ravenna**—The Bd Educ, W. J. Dorge, Clk., is having plans prepared for a 2 story, 110 x 225 ft. high school. About $375,000. O. D. Howard, 8 East Broad St., Columbus, Archt.

**Ind., Indianapolis**—The Bd. of School Comrs. plans to build a 2 story grade school on Market St. About $300,000. Snider & Rotz, 703 Merchants' Bank Bldg., Engrs., E. E. Dunlap & Co., 909 State Life, Archts.

**Ind., Logansport**—First Natl. Bank is having plans prepared for a 2 story bank including a steam heating system. About $300,000. The Arney Co., 10 South La Salle St., Chicago, Ill., Archt. and Engr.

**Ind., South Bend**—The Scottish Rite is having sketches prepared for a 4 story cathedral. About $500,000. R. G. Schmid, 154 West Randolph St., Chicago, Ill., Archt.

**Ill., Chicago**—The Fair Store is having sketches prepared for a 16 story, 90 x 180 ft. store building including a steam heating system. About $2,000,000. Mundie & Jensen, 39 South La Salle St., Archts.

**Ill., Chicago**—H. J. Schlacks, Archt., 721 North Michigan Blvd., is receiving bids for a 6 story, 95 x 219 apartment hotel, including a steam heating system, on DeWitt Court between Chestnut St. and Delaware Place. About $840,000. Owner's name withheld.

**Ill., Granite City**—The American Locomotive Co., Seymour St., Pittsburgh, Pa., plans to build a locomotive plant at the intersection of the Wabash and Terminal Railways, here. About $15,000,000.

**Wis., Clintonville**—The city will soon receive bids for water works improvements including a pumping station and the installation of one 500 g.p.m. motor driven pump, one 650 gal. and one 300 gal. pumps. L. P. Pelishek, Clintonville, Engr.

**Wis., Janesville**—The city is having plans prepared for an addition, 22 x 54 ft. and a 17 x 36 ft. wing, to the pumping station. C. V. Kerch, City Engr.

**Wis., Milwaukee**—The Bd. of Industrial Educ., 800 Manufacturers' Home Bldg., received low bid for coal handling equipment, from Hockendahl & Schmidt, 16th and Canal Sts., $8,797; and for ash handling equipment, from Amer. Steam Conveyor Corp., Wells Bldg., $5,470.

**Iowa, Waterloo**—The Masonic Temple Assn., East Park Ave. and Sycamore St., plans to build a 6 story, 120 x 142 ft. Masonic Temple. About $300,000. Architect not selected.

**Minn., Keewatin**—A. Bodah, Supt. of the Water and Light Plant, plans to make improvements, including an electrically driven vacuum pump for the boiler house; addition to boiler house for switchboard; three 37½ kva. transformers with steel outdoor substation and a 200 g.p.m. deep well pump. W. H. Gallagher, 619 Woodland Ave., Duluth, Engr.

**Minn., Minneapolis**—T. K. Kelly Sales System, 26th St. and Nicollet Ave., is having plans prepared for a 4 story, 75 x 150 ft. office building, including a steam heating system. About $250,000. Architect not announced.

**Minn., Rochester**—The city of Rochester and Olmsted County plan to build a hospital. About $700,000. L. J. Fiegel, County Aud., A. F. Wright, City Clk. Architect not announced.

**Minn., St. Paul**—The City Water Dept. received tied bids for one 54 in x 60 ft. steel return tubular boiler, from William Bros. Boiler & Mfg. Co., Nicolet Island, Minneapolis; Crane & Ordway, 5th and Rosabel Sts., St. Paul; and Kenny Boiler & Mfg. Co., 6th and Locust Sts., St. Paul; all bids $1,815.

**Minn., Virginia**—The Bd. Educ., care of C. Johnson, Chn., will receive bids in April for a 3 story, 60 x 200 ft. school with a 1 story, 50 x 80 ft. addition, including a steam heating system with mechanical ventilation. About $400,000. Kelly & Shefchik, 1007 Alworth Bldg., Duluth, Archts. and Engrs.

**S. D., Mobridge**—The State Hydro-Electric Comn., Pierre, plans to construct dams and power house here, to generate electricity for supplying cities, etc. About $15,000,000.

**Mo., St. Louis**—The Christian Brothers' College, 612 Adams St., Memphis, Tenn., plans to build a school and stadium at Clayton and Bellevue Aves., here. About $500,000. Architect not selected.

**Okla., Guymon**—The city plans an election to vote on $63,000 bonds for the purchase and enlargement of the local light plant. Ruckel Engr. Co., Hutchinson, Kan., Engr.

**Utah, Fountain Green**—The Big Springs Electric Company had plans prepared for a new power house. Plans include the installation of a generator and water wheel. E. R. Anderson, Mgr. and Engr.

**Cal., Fullerton**—The city plans to reconstruct water system to include new pumps, reservoir and distributing system. About $320,000.

**Cal., Glendale**—The city is receiving bids for furnishing and installing an electrically operated pumping plant including a centrifugal pump and 60-hp. motor, also a reservoir, 10 ft. deep, with a 300,000 gal. capacity. H. B. Lynch, 1007 Van Nuys Bldg., Los Angeles, Engr.

**Que, Montreal**—The Bd. of Water Comrs., A. E. Ducet, Engr., is designing new electrical pumping station which will provide accommodation for five pumps, each to have 30,000,000 gal. daily capacity. Bids will be received in March. About $150,000.

### CONTRACTS AWARDED

**Mass., Boston**—M. and A. Rudwick, 40 Court St., will build a 3 story, 110 x 290 ft. garage including a steam heating system. About $500,000. Work will be done by day labor.

**Mass., Dorchester** (Boston P. O.)—The Dept. of Pub. Works, Boston, has awarded the contract for furnishing and installing a pumping engine at Calf Pasture pumping station here, to Simpson Dry Dock Co., Marginal St., East Boston, at $78,453.

**N. Y., Brooklyn**—C. Goell, 1418 Carroll St., will build two 4 story, 125 x 135 ft. apartment houses including a steam heating system at Carroll and Albany Sts. About $400,000. Shampan & Shampan, 50 Court St., Archts. and Engrs. Work will be done by day labor.

**N. J., Boonton**—The Bd. Educ. has awarded the contract for the installation of heating apparatus in a new 2 story school to Johnson Heating Co., 131 East 29th St., New York City, at $12,575.

**N. J., Maurer**—The Barber Asphalt Paving Co. Land Title Bldg., Philadelphia, Pa., has awarded the contract for machinery and manufacturing buildings and a power house, here, to White Constr. Co., 95 Madison Ave., New York City. About $1,000,000. Noted Dec. 14.

**Pa., Chambersburg**—The Penn Hall Co., Edgar Ave., has awarded the contract for a 3 story, 39 x 157 ft. dormitory and a 2 story, 37 x 181 ft. administration building, including a steam heating system, to C. E. Cump, Chambersburg. About $250,000.

**Ala., Florence**—The United States Engineer's Office, War Dept., Washington, D. C. has awarded the contract for a house turbine here, to Morgan-Smith Co., York, Pa., at $60,820.

**Ky., Louisville**—The U. S. Engineer's Office, War Dept., Washington, D. C., has awarded contract for machinery for the Ohio River Lock No. 48 to H. P. Gazzam Mach. Co., 3200 Penn Ave., Pittsburgh, Pa., gate operating machinery, $6,500; J. & J. B. Milholland Co., 714 5th Ave., Pittsburgh, Pa., valve operating machinery, $7,725; C. Hegewald Co., State and Railroad Sts., New Albany, Ind., winding engines for gate operating machinery, $2,999; Vogt Bros. Mfg. Co., 1402 West Main St., Louisville, Ky., oil pump, $355.50.

**O., Berea**—The city has awarded the contract for a 2,000,000 gal. compound condensing pumping engine to the Power Plant Supply Co., 707 Canal Road, N. W., Cleveland.

**Ill., Chicago**—The Roosevelt State Bank has awarded the contract for a 2 story, 30 x 140 ft. bank including a steam heating system to A. Annis, 139 North Clark Street. About $250,000.

**Ill., Chicago**—The Illinois Iron Malleable Co., 1801 Diversey Blvd., has awarded the contract for a 1 story, 90 x 100 ft. power house to A. Rasmussen, 154 West Randolph St., About $200,000. Power plant equipment will be installed.

**Wis., Union Grove**—The State Bd. of Control, Madison, has awarded the contract for three 2 story inmate buildings and a 1 story refectory building at the Home for the Feeble-Minded here, to Immel Constr. Co., 200 Main St., Fond du Lac, at $333,236.

**N. D., Hurdsfield**—The Bd. Educ., R. H. Corson, Clk., has awarded the contract for a 2 story, 60 x 89 ft. consolidated school and a 25 x 25 ft. boiler and fuel room, to W. H. Carson, New Rockford, at $60,000.

**Cal., Los Angeles**—The Los Angeles Union Terminal Co., 746 Central Ave., has awarded the contract for a 7 story, 100 x 560 ft. warehouse including a steam heating system at 1370 East 7th St., to Wurster Contr. Co., Central Ave., at $550,000.

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